Acta Agronomica Óváriensis

D., Pásztor et al./ActAgrOvar, Vol.67.1. (2026)

Water Balance of Irrigated and Rainfed Sweet Corn in Weighing Lysimeters

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Received/Érkezett: 28.11.2025 Revised/Átdolgozva: 24.02.2026
Accepted/Elfogadva: 15.04.2026 Published/Megjelent: 29.06.2026

ABSTRACT

Weighing lysimeters are suitable tools for complex studies of the soil–water–plant–environment system. The precise determination of crop water demand and water-use efficiency (WUE) is essential for irrigation planning. In 2025, two weighing lysimeters (Lx) were used at the University of Debrecen to investigate sweet corn (*Zea mays* convar. *saccharata* var. MS Erica) under irrigated (L1) and rain-fed (L2) conditions. Sensors mewasured soil water content and meteorological data. From May to August, precipitation totaled 177 mm, while irrigation amounted to 190 mm and 50 mm in the two treatments, respectively. Cumulative evapotranspiration reached 447.6 mm in L1 and 294.4 mm in L2, with both treatments showing a negative water balance. Dry biomass was 2418 g (L1) and 1588 g (L2), with WUE values of 6.6 and 7.0 g mm^{-1}. The results highlight the trade-off between yield increase and water-use efficiency. The research presented in the article was carried out within the framework of the Széchenyi Plan Plus program, with support from the RRF 2.3.1-21-2022-00008 project.
Keywords: weighing lysimeter, evapotranspiration, water use efficiency, irrigation management, sweet corn

1. LITERATURE REVIEW

Maize is one of the world's most extensively cultivated crops and serves as a major food and feed source (Nagy, 2010). Owing to its substantial water demand, it is particularly sensitive to variations in water supply, and weather conditions strongly influence its yield stability during the growing season. Among the different types, sweet maize generally exhibits a higher water requirement and greater sensitivity to water availability than grain maize. With the increasing frequency of heat and water-stress events and the decline in available freshwater resources due to climate change, efficient water use has become a key priority. Irrigation plays a crucial role in maintaining yield stability and crop quality; however, from a sustainability perspective, improving water-use efficiency has become ever more important (FAO, 2002; Fereres & Soriano, 2006; Pereira et al., 2012).

Maize water demand varies considerably across its phenological stages, with the tasseling–silking phase being the most critical for water supply, as water deficits during this period can drastically reduce yield. The total evapotranspiration requirement of the crop throughout the growing season typically ranges from 450 to 800 mm, depending on cultivar, soil characteristics, and climatic conditions (Allen et al., 1998; Carr, 2013). The dual crop coefficient approach described in the FAO-56 guidelines has become the most widely adopted method for irrigation scheduling and accurate assessment of crop water use, as it enables the separate quantification of soil evaporation and plant transpiration components (Allen et al., 1998; Allen et al., 2011).

Lysimeters are among the most precise field instruments for studying the soil–plant–water continuum (Zsembeli & Kovács, 2006). Weighing lysimeters allow direct measurement of all components of the water balance (precipitation, irrigation, percolation, and evapotranspiration), thus providing an excellent tool for quantifying crop water use and analysing hydrological processes. Lysimeter data provide a reliable basis for developing irrigation strategies and validating physically based hydrological models (Allen et al., 2011).

Modern weighing lysimeters use high-precision load cell systems capable of detecting mass changes as small as 0.01 mm of water loss, allowing accurate tracking of daily evapotranspiration (Evett et al., 2012; Howell, 2001). Despite this high accuracy, potential sources of error must be considered, such as those arising from rainfall collection, wind effects, and the temporal distribution of percolation. Recent European studies, including the Austrian and German TERENO and BOKU lysimeter networks, have further developed methodologies that enable the reproducible determination of seasonal and annual water balance components (Hannes et al., 2015).

In recent decades, global research efforts have increasingly focused on improving agricultural water-use efficiency, particularly in arid and semi-arid regions where water scarcity threatens the sustainability of agricultural production. With the expansion of precision agriculture, technologies that rely on real-time data for irrigation management have become widespread. The integration of sensor-based monitoring and modelling approaches enables detailed temporal and spatial characterisation of water fluxes, thereby supporting decision-support systems (Evans & Sadler, 2008; Jones, 2004). Lysimeter data serve as essential reference measurements in such systems, providing direct physical validation of modelled evapotranspiration values (Irmak et al., 2016).

Water-use efficiency (WUE) in crops depends not only on genetic traits but also on irrigation techniques and soil physical conditions. Experimental results indicate that micro-irrigation, strip or deficit irrigation, and soil moisture-based irrigation control can enhance WUE to varying degrees (Geerts & Raes, 2009; Zhang et al., 2017). Adaptive plant responses – such as increased rooting depth or stomatal regulation – may improve efficiency under moderate stress, whereas excessive water supply can paradoxically reduce WUE (Sinclair et al., 2010). Consequently, increasing water-use efficiency entails complex ecological and physiological trade-offs.

In Hungary's continental climate, summer precipitation deficits often lead to severe yield losses (Pálfai, 2004). Maize is particularly drought-sensitive in the Great Hungarian Plain, making irrigation

DOI: 10.17108/ActAgrOvar.2026.67.1.6

a key element of yield security. Observations over recent decades show that the frequency and duration of dry periods have increased, accompanied by a 5-15 % rise in potential evapotranspiration (Bartholy & Pongrácz, 2010; Spinoni et al., 2015). Analyses of European and Hungarian drought indices (SPEI and SPI) revealed that the number of drought days and negative soil moisture anomalies are expected to increase further in the future, particularly across the Great Hungarian Plain (IPCC, 2021; Seneviratne et al., 2012; Vicente-Serrano et al., 2010).
The spatial and temporal redistribution of water resources is particularly pronounced in the Carpathian Basin due to its climatic characteristics. Regional hydrological modelling studies have demonstrated a close relationship between groundwater level variations, evaporation balance, and changes in land cover and irrigation extent (Fehér, 2019; Tamás et al., 2022). Research findings also emphasise that irrigation can induce local microclimatic effects, such as increased air humidity and mitigation of temperature extremes, which feed back into the regional water balance, meaning that agricultural water use can exert detectable climatic impacts, even at the modelling scale (Báder, 2023; Lobell et al., 2006).
As drought conditions intensify, the optimal maize-growing zones are projected to gradually shift northward, leading to a spatial redistribution of agricultural production. Such climate-induced regional shifts pose new challenges to the global maize trade and food security (Leng & Hall, 2019). According to Porfirio et al. (2018), the increasing frequency of drought years may shrink traditional maize-growing regions, whereas previously marginal areas could emerge as new potential production zones.
Integrating lysimeter data into hydrological and agrometeorological models is crucial for improving model calibration and the accuracy of mesoscale estimations. Physically based models, such as MIKE SHE or AquaCrop, can reproduce real water dynamics only when calibrated with field-measured evapotranspiration and soil moisture data (Groh et al., 2020; Steduto et al., 2009). The lysimeter research conducted at the University of Debrecen aligns with this international trend, providing experimental data that facilitate parameter refinement and enhance the reliability of spatial extrapolation.
In Hungary, maize cultivation under rainfed conditions remains particularly risky in areas classified as conditional irrigation zones (Magyar et al., 2023). Several studies have examined the relationship between water requirements and WUE (García y García et al., 2009; Szalókiné Zima, 2023). Therefore, it is essential to understand the differences in yield and water use between irrigated and non-irrigated conditions. Water-use efficiency, expressed as the ratio of biomass production to water consumed through evapotranspiration, is a key indicator for evaluating plant water management performance (Blum, 2009; Richards & Townley-Smith, 1987). Because lysimeter measurements capture total evapotranspiration, actual WUE values are typically lower than those estimated from transpiration alone. Advanced models such as AquaCrop provide a means to account for these differences and to optimise deficit-irrigation strategies (Hatfield & Dold, 2019; Steduto et al., 2009).
The objective of this study was to compare the water balance and water-use efficiency of irrigated and rainfed sweet maize using two precision weighing lysimeters. Continuous monitoring of precipitation, irrigation, soil moisture, and evapotranspiration (ET) was performed in parallel with biomass measurements to quantify crop water productivity. These findings contribute to the development of irrigation strategies for sweet maize and offer new insights into the complex interactions within the soil-plant-water system.

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2. MATERIALS AND METHODS

Our research was conducted in Debrecen, Hungary, at the courtyard research facility of the Institute of Water and Environmental Management, University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management. The site is located in a lowland environment typical of the Great Hungarian Plain (*Figure 1*), characterized by a continental climate with frequent summer drought. The soil placed in the lysimeters was collected from Látókép, approximately 15 km from Debrecen, and was classified as meadow chernozem. This soil type represents the regional pedological conditions well, with medium water-holding capacity, making it suitable for investigating soil–water balance processes.

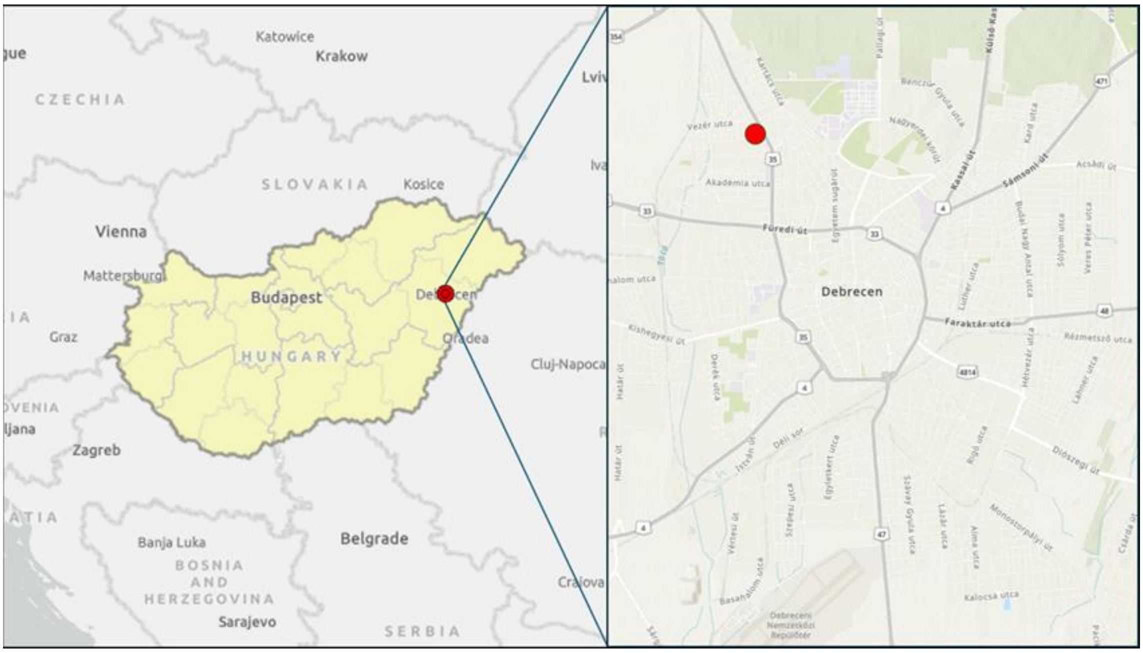

Figure 1: Location of the experimental site in Hungary and the Debrecen region

Source: Authors' data

The mean annual precipitation in the area is approximately 560 mm, although the seasonal distribution is highly variable. *Figure 2* presents the total annual precipitation for the period 2015-2024, compared with the 30-year climatological average (1991-2020). More than half of the examined years fell below the long-term mean; thus, six out of ten years were classified as dry and only two as wetter-than-average. Meteorological data were obtained from the Debrecen (Kismacs) station of the Hungaromet Automatic Station Network, which records precipitation, air temperature, relative humidity, and potential evapotranspiration (PET) calculated using the Antal method (Antal, 1968).

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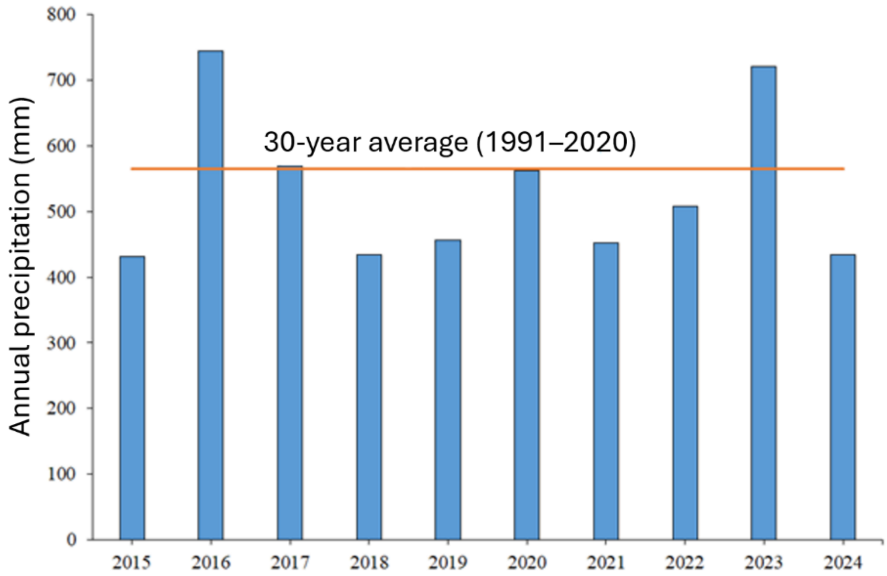

Figure 2: Annual precipitation totals compared to the 30-year average (1991–2020) in the Debrecen region

Source: Authors' analysis based on Hungaromet data

Our experiment employed two UGT Ready-To-Go Lysimeter 800/900 units, each with a 0.5 m² surface area and 0.9 m soil monolith depth (*Figure 3*). Each lysimeter was equipped with load cells for continuous mass measurement. Sensors were installed at depths of 20, 40, and 60 cm; however, because sweet corn has a shallow rooting depth, only data from 20 and 40 cm were used for evaluation. The instrumentation included tensiometers, soil moisture sensors, soil temperature sensors, and one reference tensiometer positioned outside the lysimeters to monitor ambient soil conditions. Rainfall, air temperature, humidity, and global radiation were measured by sensors located 1 m from the lysimeter tanks (*Figure 6*).

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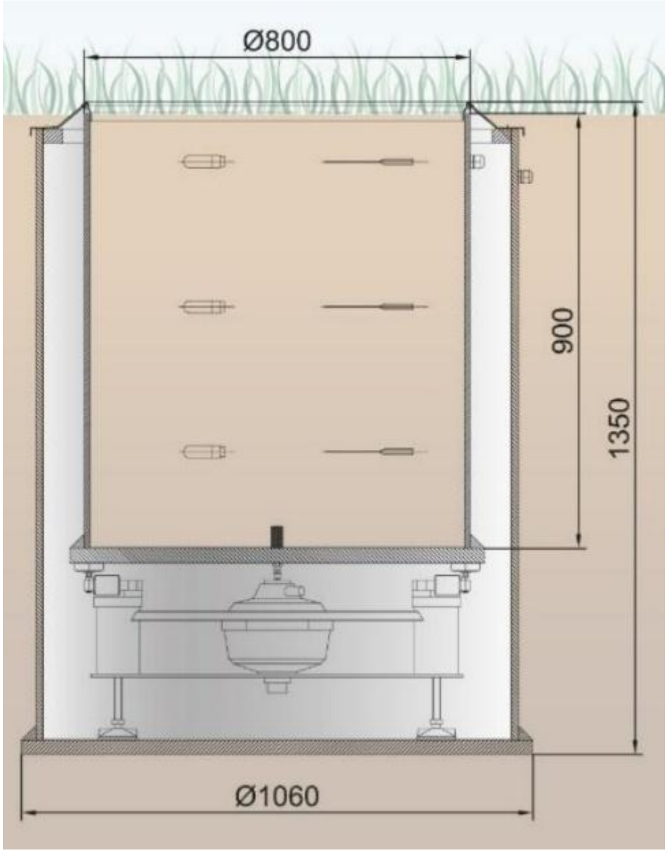

Figure 3: Cross-section of the weighing lysimeter system

Source: Umwelt-Geräte-Technik GmbH., n.d.-b

The variations in soil temperature are shown in *Figure 4a* and *4b*. In both lysimeters, the upper 0-20 cm layer responded rapidly to daily temperature fluctuations, whereas changes in the deeper 20-40 cm layer were attenuated. The highest temperatures occurred in late June and early July, exceeding 28-30 °C.

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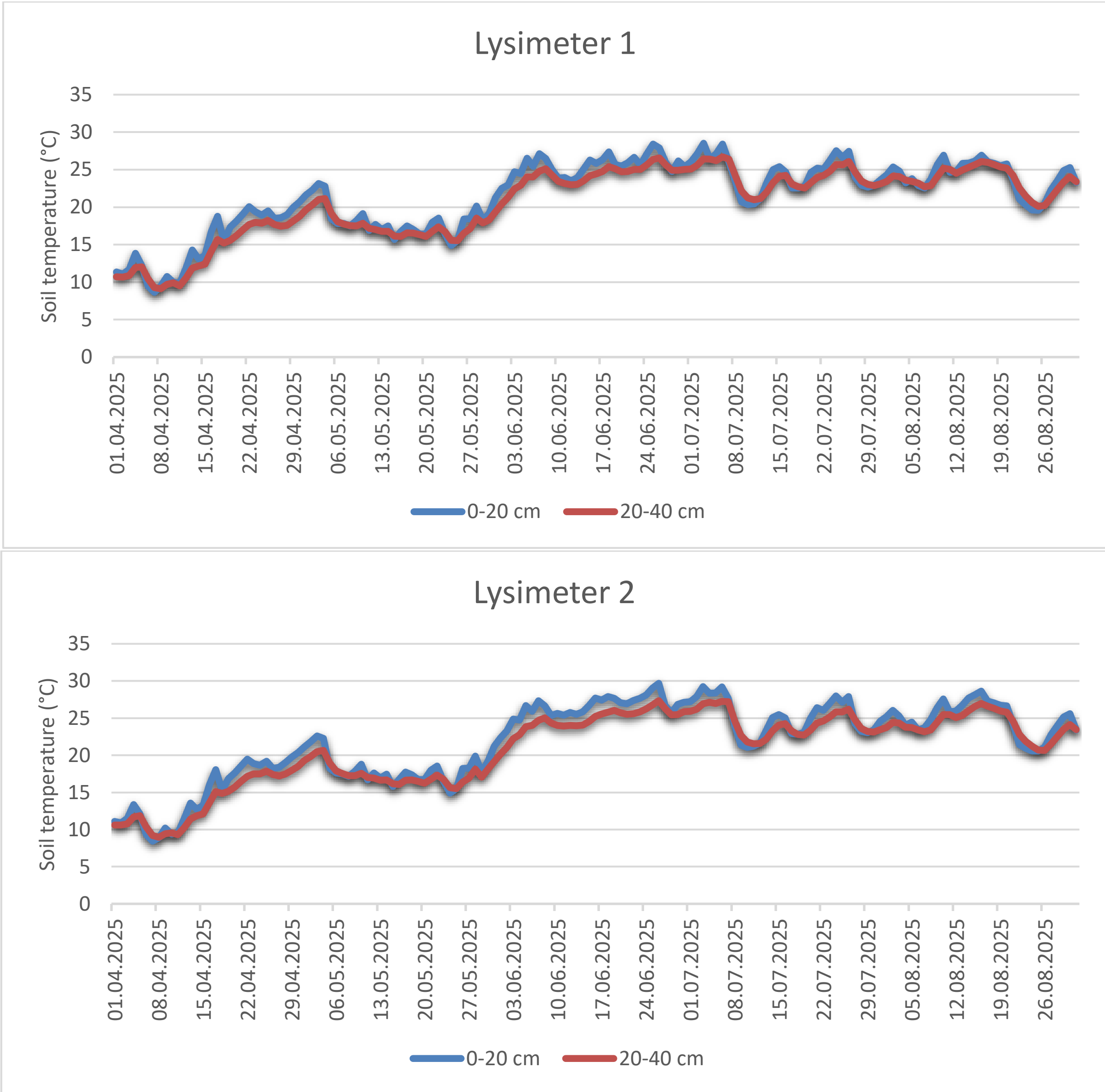

Figure 4a and 4b: Soil temperature variation at different depths in L1 and L2

Source: Authors' data

The lysimeter mass data were recorded continuously at 15-minute intervals. Precipitation was measured using a meteorological station, and irrigation was applied at predetermined doses. Percolating water was collected through drainage outlets at the bottom of the lysimeters and measured directly. Evapotranspiration (ET) was calculated using the water-balance equation, accounting for incoming (precipitation + irrigation) and outgoing (evaporation + percolation) components as well as changes in lysimeter mass over time (*Figure 5*). This approach enabled precise monitoring of water fluxes within the soil-plant system.

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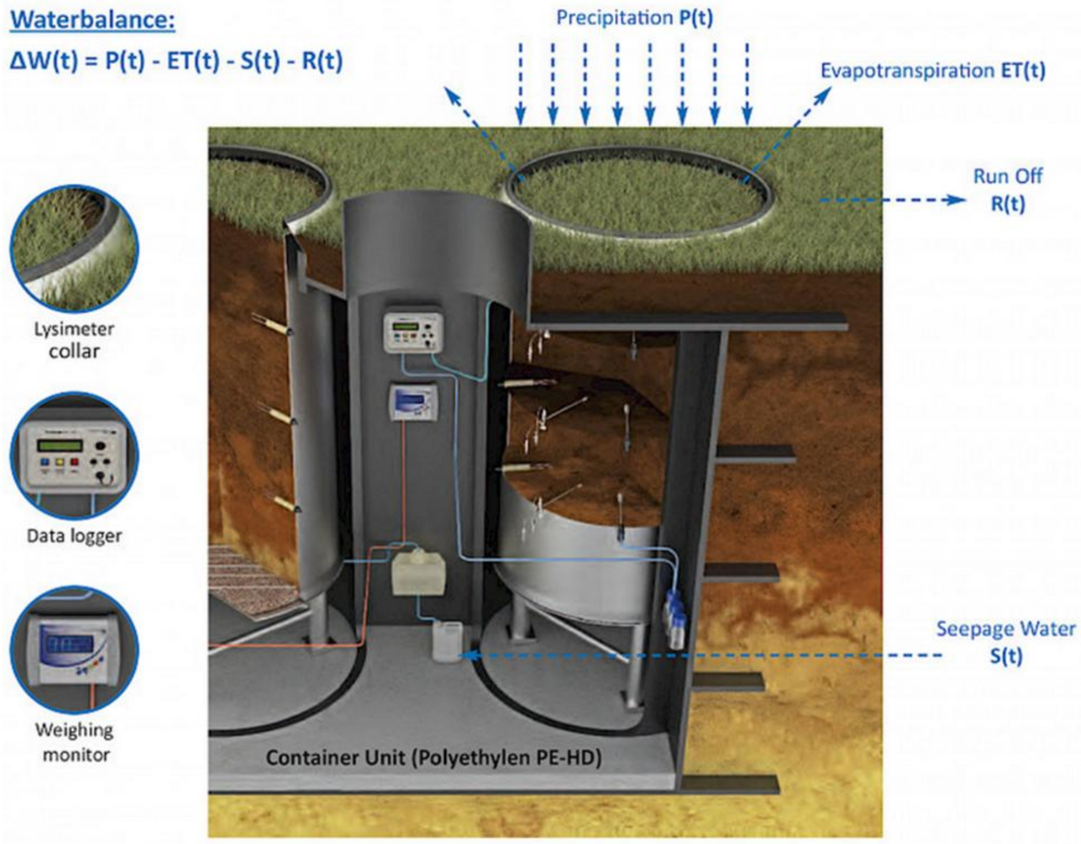

Figure 5: Determination of main water-balance components using a weighing lysimeter

Source: Umwelt-Geräte-Technik GmbH., n.d.-a

Meteorological data were obtained from the Hungaromet automatic station (in .csv format), and time series from the weighing lysimeters and local weather stations (also in .csv format) were compared to determine the individual water balance components. After synchronising the datasets to a unified temporal resolution, verifying time-series consistency, and filtering erroneous records, daily evapotranspiration (ET) and water-use efficiency (WUE) were computed. Data processing, parameter calculation, and graphical visualisation were performed using Microsoft Excel 2024.

The experiment utilised the sweet corn variety *Zea mays* convar. *saccharata* var. MS Erica (*Figure 6*). This medium-maturity hybrid, bred for fresh consumption and industrial processing, develops strong stalks and uniform cobs with 18-20 kernel rows. Owing to its stable yield and favourable water response, it is well-suited for assessing the effects of irrigation. Sowing took place on 16 May 2025, following 25 cm of tillage and loosening. A 10 mm irrigation was applied after sowing to ensure uniform emergence.

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Figure 6. Experimental setup of the sweet corn lysimeter trial and crop stand at the early growth stage

Source: Authors' photo

Two treatments were established: L1 (irrigated) and L2 (rainfed, with only initial irrigation). During the growing period (May-August), total precipitation amounted to 177 mm, indicating a moderately dry season with pronounced monthly variability; most rainfall occurred in July (94 mm), while May and August each received approximately 25 mm (*Figure 7*). In the irrigated treatment (L1), an additional 190 mm of water was applied, whereas the rainfed unit (L2) received only 50 mm of supplementary water during the early growth stage to ensure germination. Irrigation in L1 was applied at 10 mm doses, typically once per week, with irrigation timing determined by crop water demand and prevailing weather conditions. Water applications were concentrated primarily during vegetative development and the reproductive phase, with increased frequency during dry periods (*Figure 8*).

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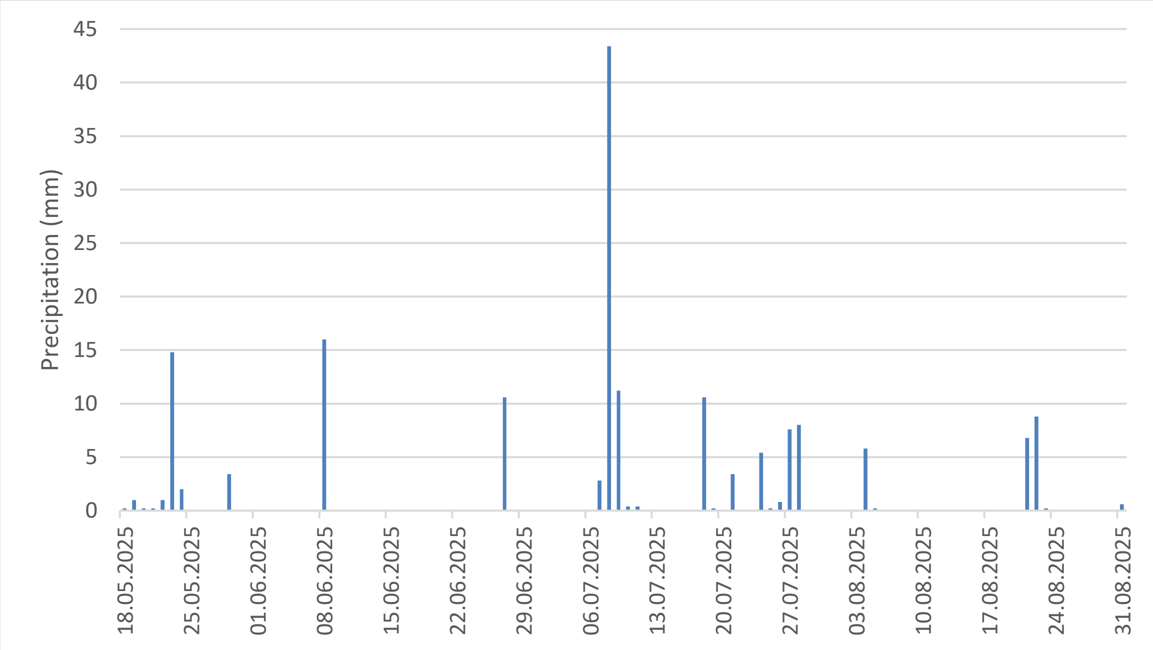

Figure 7: Daily precipitation totals during the experimental period

Source: Authors' data

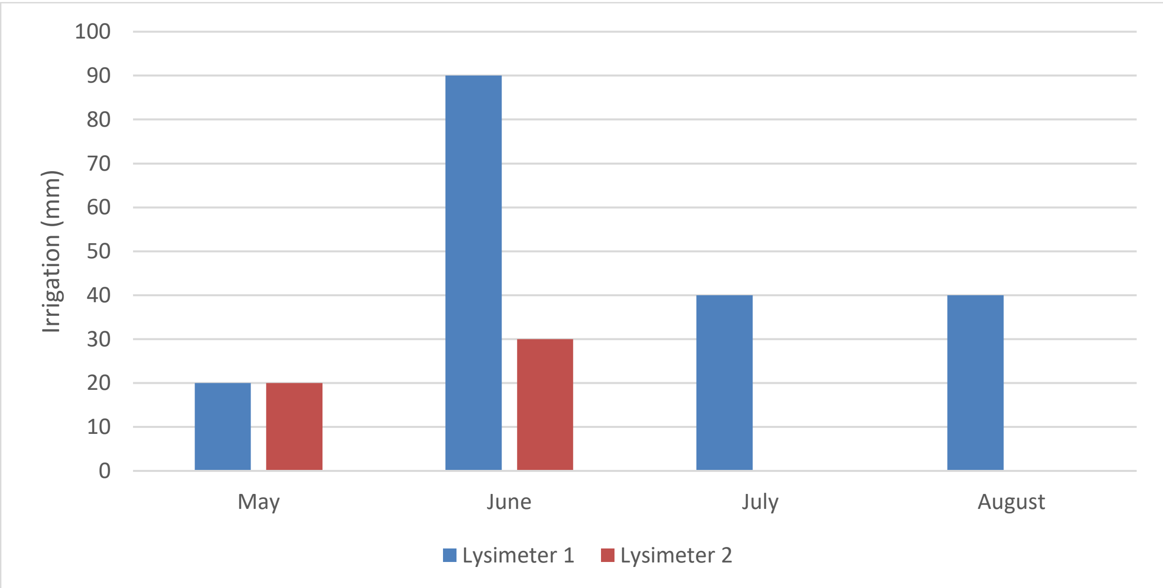

Figure 8: Irrigation schedule and applied water amounts for L1 and L2

Source: Authors' data

The soil water status was evaluated based on tensiometer readings (*Figure 9a* and *9b*). In the irrigated lysimeter (L1), soil water potential values stabilised at low tension levels during the mid-season, reflecting regular replenishment. In contrast, the rainfed L2 unit showed an increasing water deficit in the 20-40 cm layer, reaching 15-20 kPa in July. This difference clearly demonstrates the moisture-stabilising effects of irrigation.

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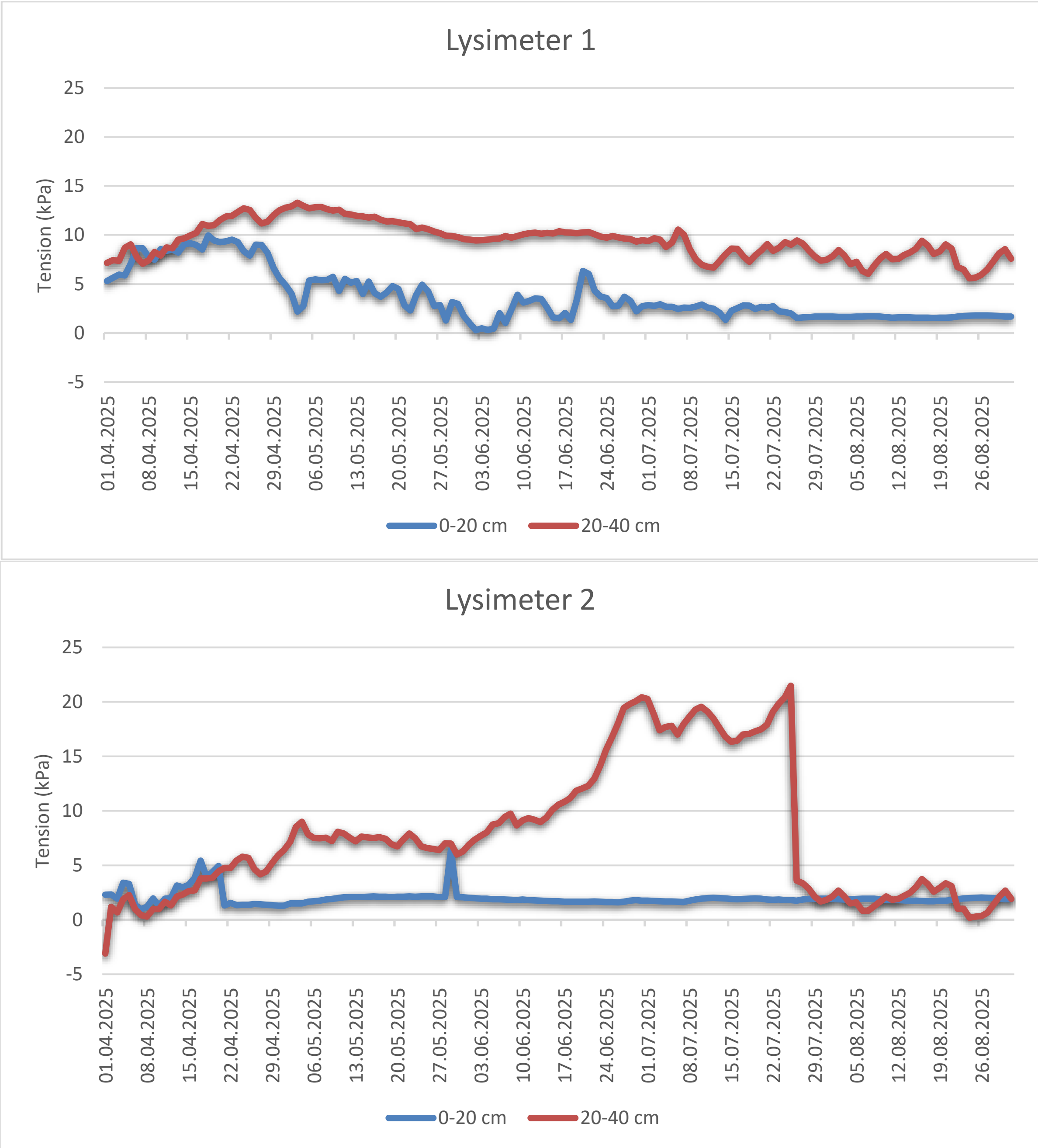

Figure 9a and 9b: Variation of soil-water potential (tension) during the growing season in L1 and L2

Source: Authors' data

Harvesting was conducted in two stages corresponding to full cob maturity. Ear length and mass were measured (*Figure 10a* and *10b*), and dry biomass was determined at the end of the vegetation period for both treatments.

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Figure 10a and 10b. Harvested sweet corn ears at the two sampling dates

Source: Authors' photo

Water-use efficiency (WUE) was calculated as the ratio of dry biomass yield to total water input (precipitation + irrigation) (*Eq. 1*) (Magaia, 2017). This enabled a direct comparison between irrigated and rainfed systems and revealed the relationship between yield increase and water-use efficiency.

$$WUE = \frac{maize\ grain\ yield\ (g\ m{-}^{2})}{seasonal\ crop\ water\ use\ \ (mm)} \qquad (1)$$

3. RESULTS AND DISCUSSION

The daily mass variation curves of the soil monoliths (*Figure 11*) illustrate the balance among precipitation, irrigation, and water loss (evapotranspiration + percolation). Positive peaks corresponded to water input events (irrigation or showers), whereas negative slopes represented storage depletion. During June and July, a sustained mass decrease was observed in both lysimeters. In the irrigated L1 unit, the larger-amplitude recharge peaks clearly followed irrigation events. In early July, several short, sharp positive impulses (rain showers) also appeared in the non-irrigated L2 unit, followed by rapid declines, indicating intensification

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of water stress. By August, daily fluctuations had diminished, and both curves approached equilibrium as crop maturation and reduced evapotranspiration (ET) drove them toward equilibrium.

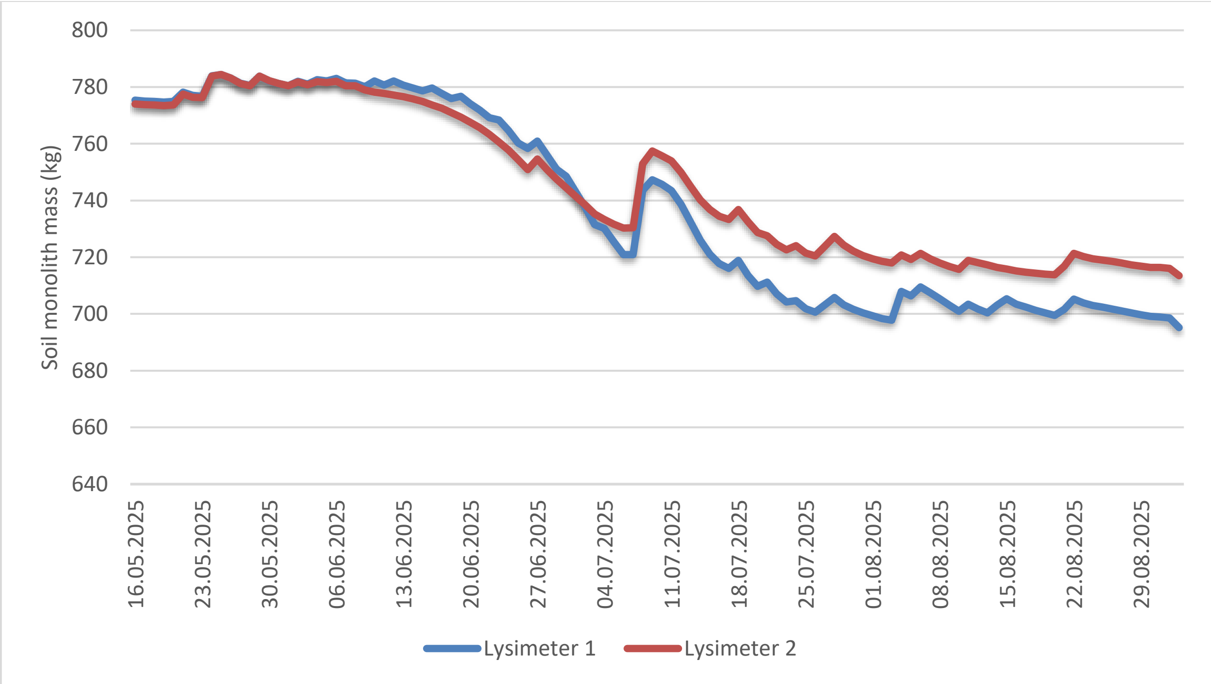

Figure 11. Daily mass variations of the soil monoliths during the growing season in L1 and L2

Source: Authors' data

Based on the combined effects of precipitation and irrigation, the seasonal water balance of the two lysimeters showed marked differences. Total water input (precipitation + irrigation) reached 367 mm in L1 and 227 mm in L2. The contrast was most pronounced in June-July, when the difference between water availability and evaporative demand reached its peak. Seepage water appeared at the beginning of the season in both lysimeters, but in negligible amounts (*Figure 12a* and *12b*).

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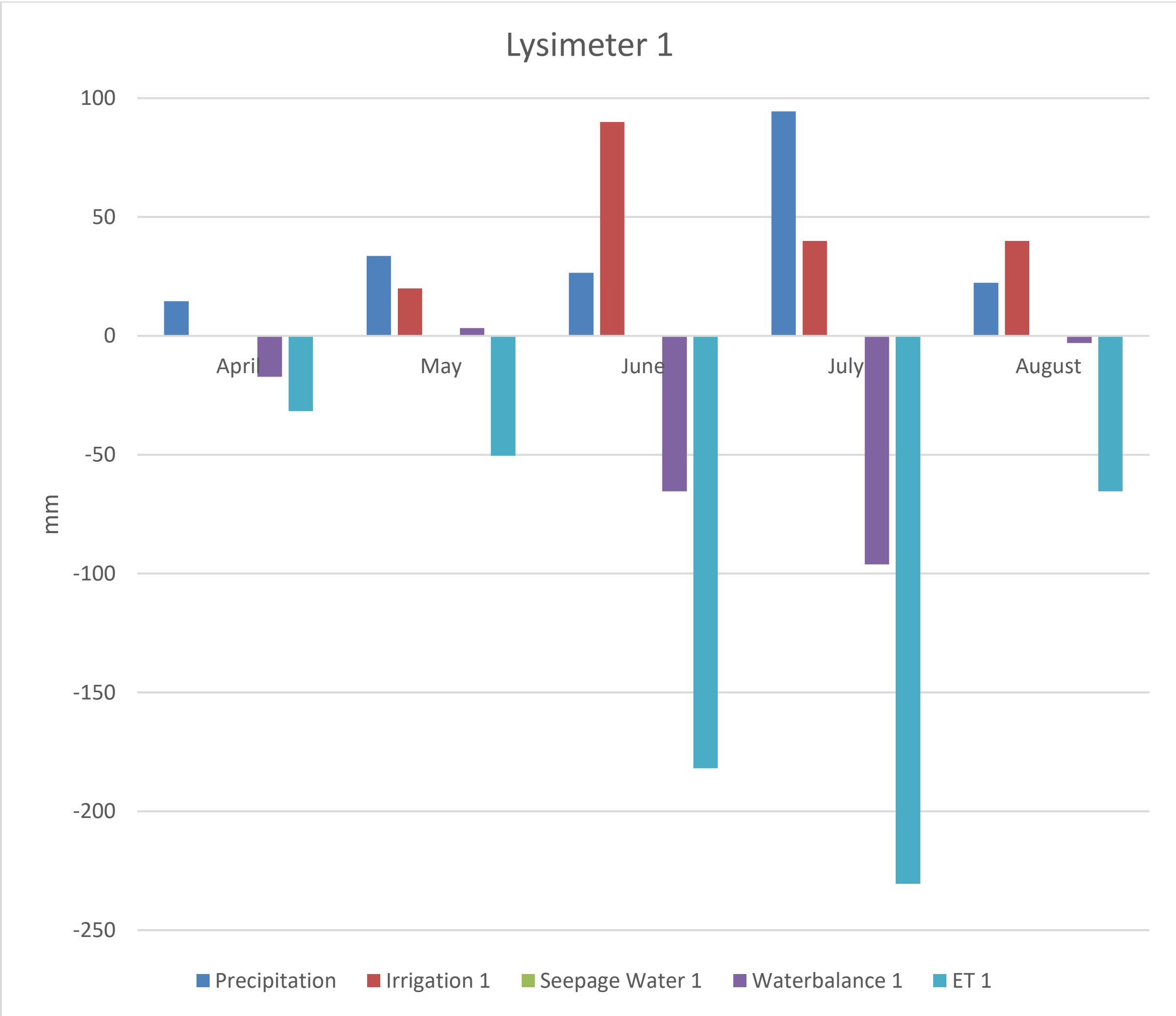

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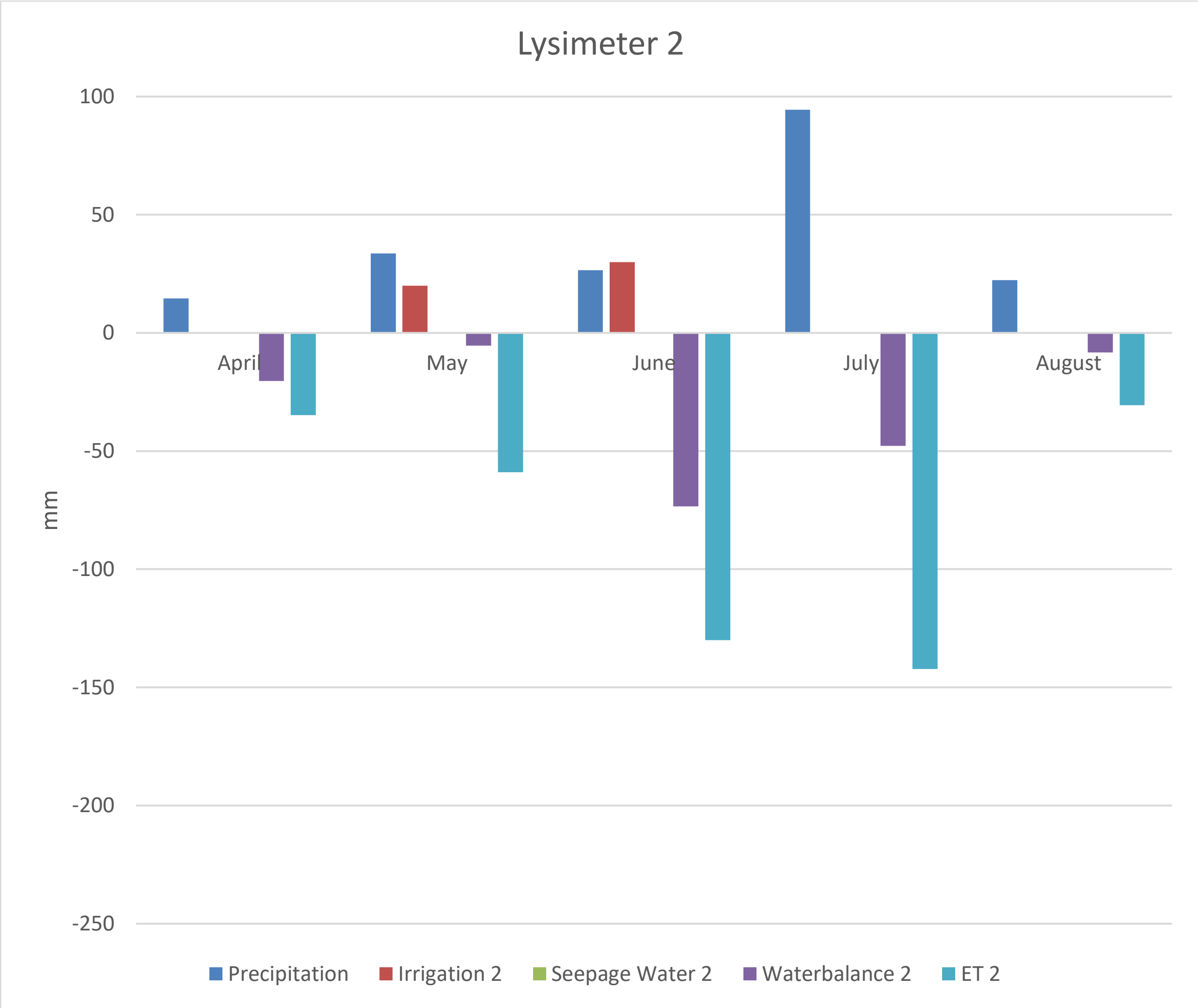

Figure 12: Monthly variation of main water-balance components in L1 and L2

Source: Authors' data

The potential evapotranspiration (PET) and lysimeter-derived actual evapotranspiration (ET) values (*Figure 13a* and *13b*) clearly demonstrate the influence of water supply on crop water use. PET represents the theoretical maximum, determined by meteorological conditions, that the irrigated L1 approached, particularly during the mid-season. In the non-irrigated L2, ET consistently fell below PET, particularly in late June and early July, reflecting the plants' physiological response to water deficit: stomatal closure and reduced transpiration.
The cumulative ET curves highlight the effect of irrigation; ET remained consistently higher in L1 than in L2. By the end of the experiment, cumulative ET reached 447.6 mm in the irrigated treatment and 294.4 mm in the non-irrigated treatment – a 52 % difference.

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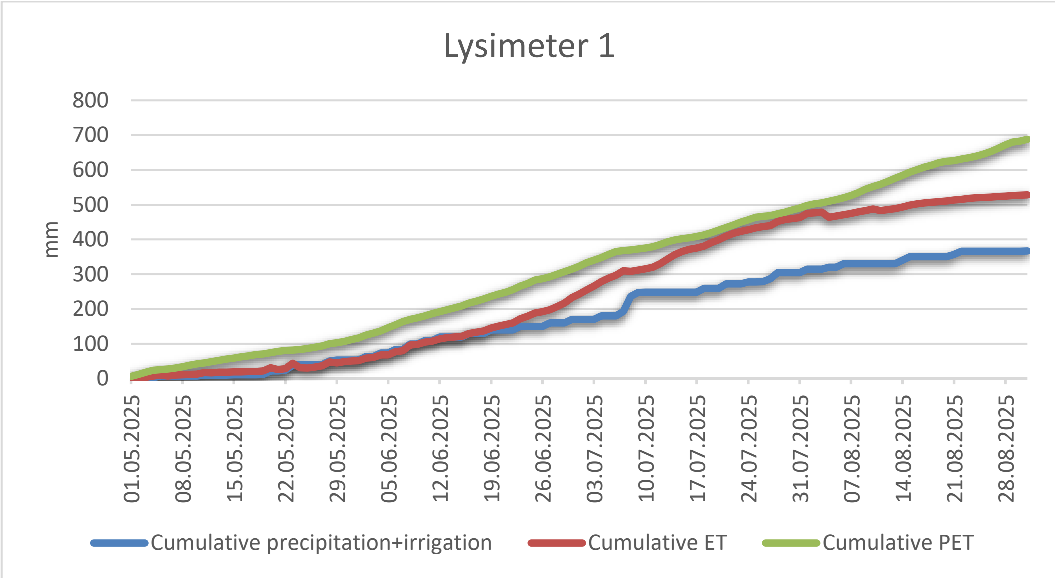

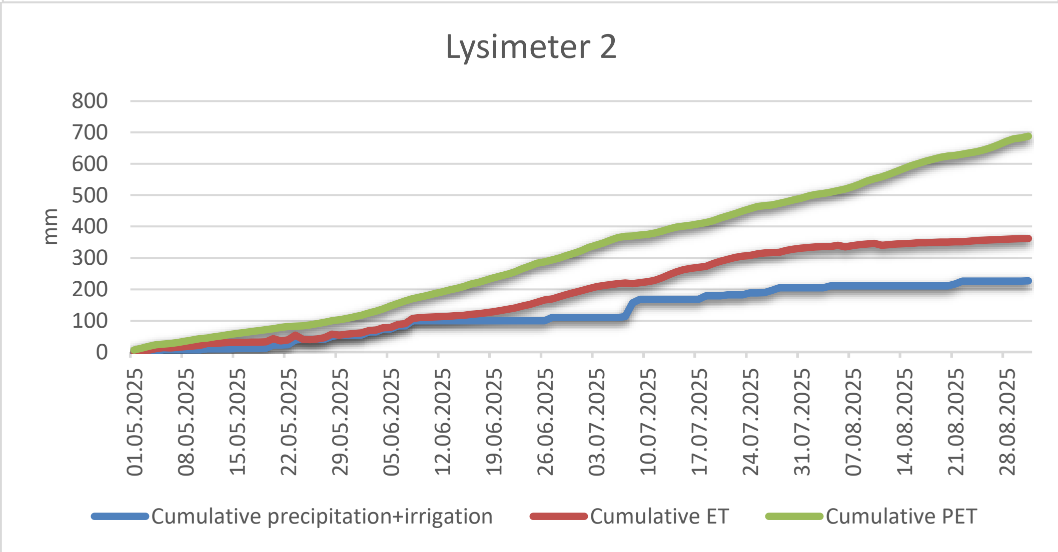

Figure 13a and 13b: Cumulative precipitation, irrigation, ET, and PET during the growing season in L1 and L2

Source: Authors' data

The monthly change in soil water storage (ΔS) reflected the utilisation of soil moisture reserves in both lysimeters (*Figure 14*). In May, a slight increase was observed (L1: +11.8 mm; L2: +14.5 mm), followed by pronounced depletion in June (L1: –65.4 mm; L2: –73.4 mm), consistent with rising ET. The largest drawdown occurred in July, particularly in the irrigated treatment (L1: –96.1 mm), whereas the non-irrigated L2 treatment showed a smaller decline (–47.8 mm) due to reduced transpiration under drought. In August, both systems approached near-equilibrium.

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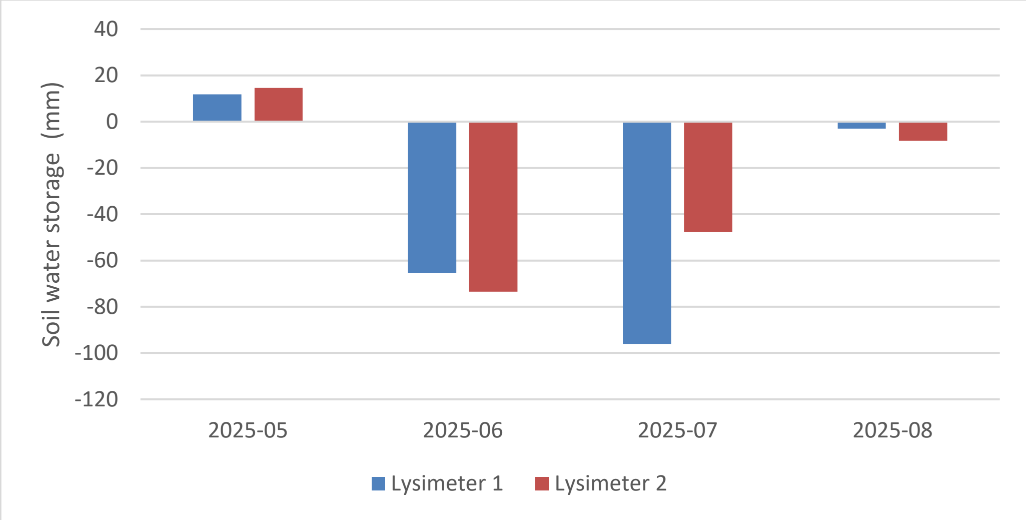
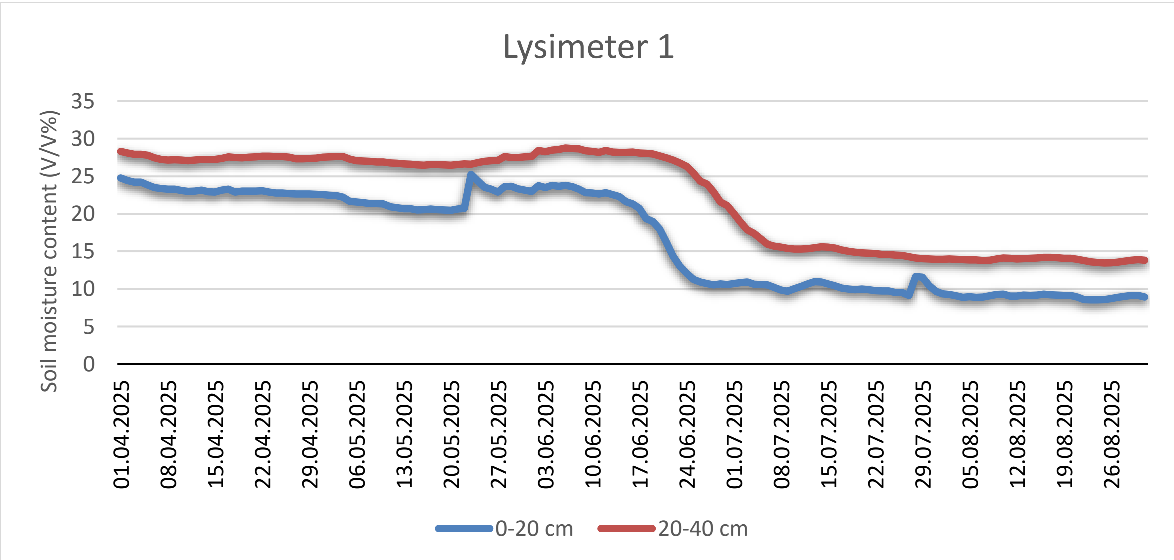


Figure 14: Monthly variation in soil water storage during the vegetation period in L1 and L2

Source: Authors' data

The temporal dynamics of soil moisture (*Figure 15a* and *15b*) also emphasised the differences between treatments. In the irrigated L1, moisture in the upper 0-20 cm layer gradually decreased from late May and then stabilised between 15 and 25 V/V% due to regular irrigation. The 20-40 cm layer responded more slowly but followed the same irrigation pattern. In the non-irrigated L2, the upper layer rapidly dried from late June onward, persistently dropping below 10 V/V%. The deeper layer also declined gradually, showing only short-term recovery after the July rain events. These results confirm that without irrigation, soil water reserves cannot meet crop demand during critical growth stages.



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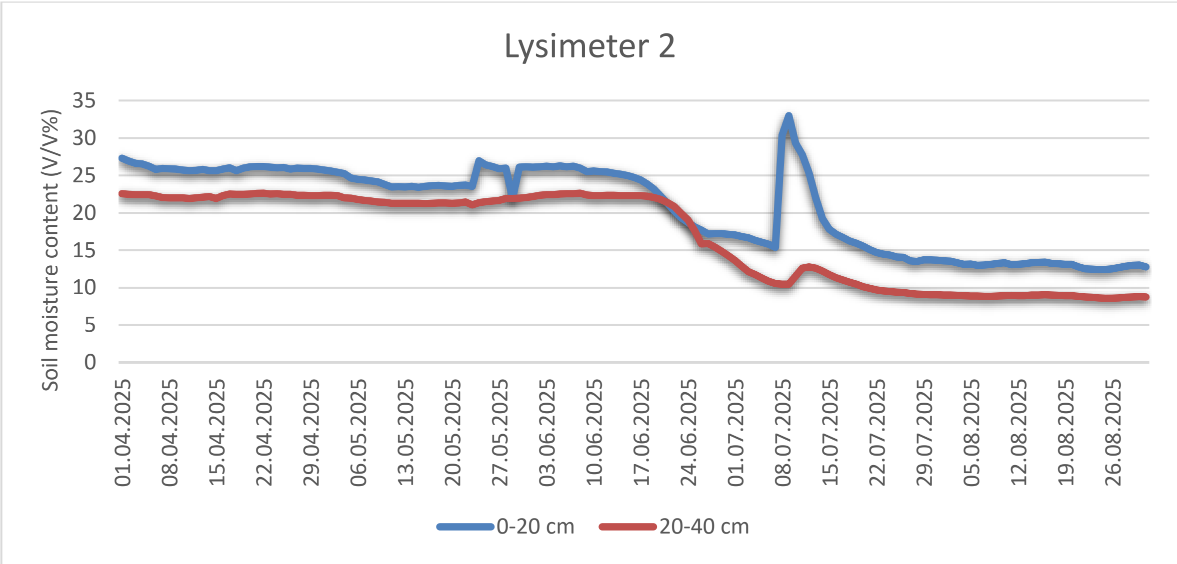

Figure 15a and 15b: Temporal variation of soil moisture at different depths in L1 and L2

Source: Authors' data

Daily ET values (*Figure 16*) reflect the actual water use of the crop canopy. Early in the season (May), both treatments exhibited low ET rates (0-2 mm day^{-1}). From mid-June onward, ET increased markedly, reaching peaks of 6-7 mm day^{-1} in the irrigated L1 and 4-5 mm day^{-1} in the non-irrigated L2. This contrast was most pronounced during hot, dry periods, driven by higher transpiration rates in irrigated plants. Toward the end of July, ET declined in both treatments, marking the closure of the water-use phase by August.

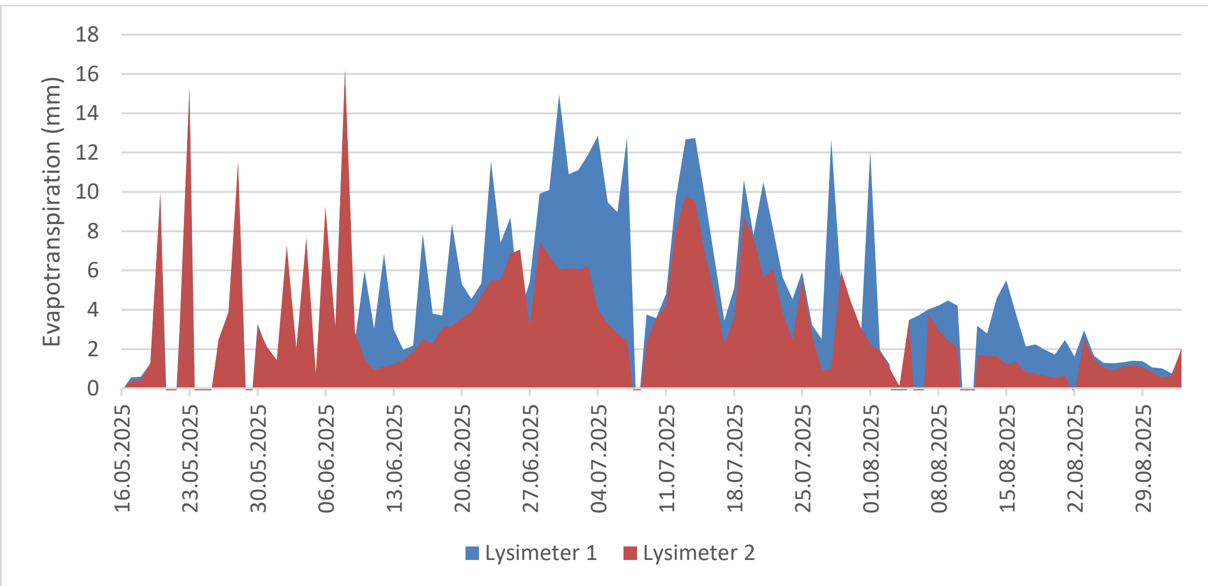

Figure 16: Daily evapotranspiration rates under irrigated and non-irrigated conditions in L1 and L2

Source: Authors' data

Dry biomass production reached 2418 g in the irrigated treatment and 1588 g in the rainfed treatment (*Figure 17*) – a ~52 % difference closely linked to water availability and seasonal ET totals.

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Water-use efficiency (WUE) was 6.6 g mm^{-1} in L1 and 7.0 g mm^{-1} in L2, indicating that irrigation increased yield but reduced the biomass produced per unit of water, representing the classical yield–efficiency trade-off.

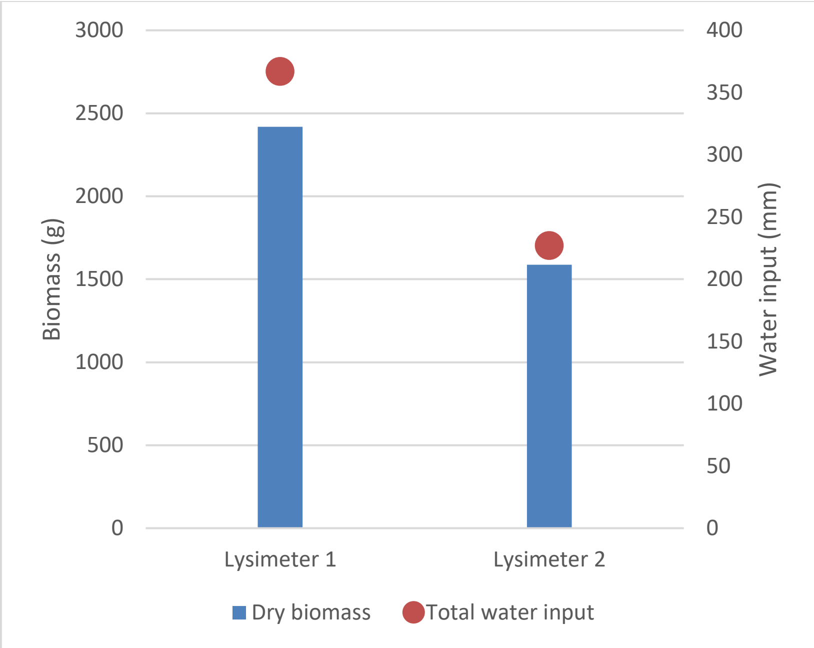

Figure 17: Relationship between dry biomass yield and water supply in L1 and L2

Source: Authors' data

According to the harvest measurements, the mean ear weight was 251 g for L1 and 237 g for L2 (*Figure 18*). The mean ear length was 18.4 cm and 18.1 cm, respectively (*Figure 19*). This irrigation not only enhanced biomass but also slightly improved ear size and uniformity. In the rainfed treatment, smaller ears and lower dry mass reflect the constraining effect of water deficit.

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Figure 18: Average ear weight at the two harvest dates in L1 and L2

Source: Authors' data

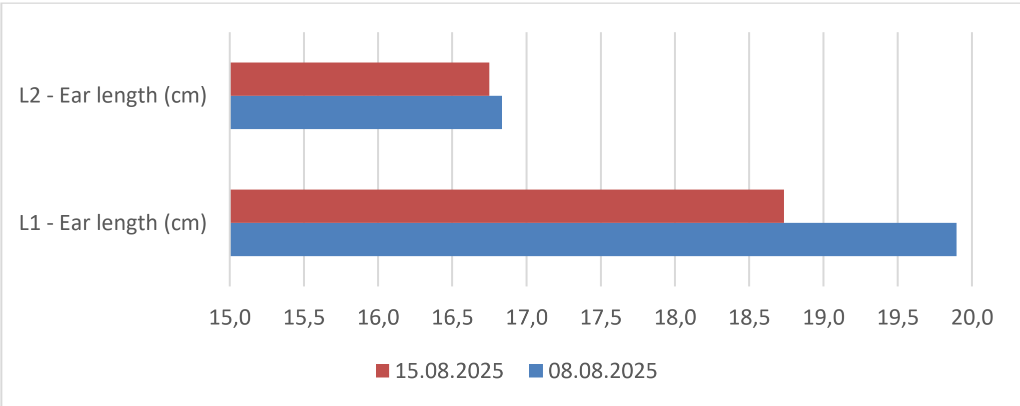

Figure 19: Variation in ear length under irrigated and non-irrigated treatments in L1 and L2

Source: Authors' data

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4. CONCLUSION

The lysimeter experiment highlighted the decisive role of irrigation in regulating water balance and sweet corn yield. In the irrigated L1, cumulative ET reached 447.6 mm, exceeding that in the non-irrigated L2 by 52 %. Irrigation enables the crop to approach potential evapotranspiration and supports greater biomass accumulation.
In the rainfed treatment, water deficit became evident from mid-June onward; the ET/PET ratio fell below 0.65, and daily water use declined due to stomatal closure and reduced transpiration. The soil water storage data showed that the most pronounced depletion occurred in June-July, when water shortages most severely limited uptake.
Biomass production was 52 % higher in the irrigated treatment, confirming a direct relationship between water supply and growth intensity. In contrast, the smaller ears and lower dry mass observed in the non-irrigated system may indicate a water-deficit-induced stress response, potentially associated with premature senescence and incomplete kernel filling.
Water-use efficiency was slightly higher under deficit conditions (7.0 g mm^{-1}) than in the irrigated treatment (6.6 g mm^{-1}), indicating more efficient carbon assimilation per unit of water under limited supply. This yield-efficiency trade-off encapsulates the core dilemma of optimising water use in semi-arid environments.
Overall, irrigation not only increased total water flux but also stabilised crop physiological function. The transpiration reduction observed under rainfed conditions represented a natural water-saving adaptation, whereas the enhanced water use in the irrigated system supported greater biomass production. The significance of lysimeter-based measurements lies in their ability to precisely quantify individual water balance components, providing a robust basis for developing precision irrigation strategies.
Future research should integrate real-time sensor data (tensiometers, soil moisture probes, and temperature probes) and modelling analyses (water-balance simulation and WUE time series) to refine predictions of crop water dynamics and advance sustainable irrigation management under Central European climatic conditions.

Acknowledgments

The research presented in the article was carried out within the framework of the Széchenyi Plan Plus programme, with support from the RRF-2.3.1-21-2022-00008 project.

 DOI: 10.17108/ActAgrOvar.2026.67.1.6

Öntözött és öntözetlen csemegekukorica vízmérlegének vizsgálata súlyliziméterekben

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ÖSSZEFOGLALÁS

A súlyliziméterek alkalmas eszközök a talaj-víz-növény-környezet rendszerek komplex vizsgálatára. A növényi vízigény és a vízhasznosítási hatékonyság (WUE) pontos meghatározása elengedhetetlen az öntözéstervezéshez. 2025-ben Magyarországon a Debreceni Egyetem területén két súlyliziméterts (Lx) állítottunk be a csemegekukorica (*Zea mays convar. saccharata var. MS Erica*) vizsgálatára öntözött (L1) és öntözetlen (L2) körülmények között. Szenzorok mérték a talajnedvességet, a talajhőmérsékletet és a meteorológiai adatokat. Májustól augusztusig a csapadék mennyisége 177 mm volt, míg az öntözés 190 mm (L1), illetve 50 mm (L2) volt. A kumulatív evapotranszspiráció az L1 esetében elérte a 447,6 mm-t, az L2 esetében pedig a 294,4 mm-t, így mindkét kezelés negatív vízmérleget mutatott a vizsgált időszak végére. A száraz biomassza tömege 2418 g (L1) és 1588 g (L2) volt, 6,6 és 7,0 g mm^{-1} WUE-értékek mellett. Az eredmények rávilágítanak a hozamnövekedés és a vízhasznosítás közötti kompromisszumra. A dolgozatban bemutatott kutatás a Széchenyi Terv Plusz program keretében valósult meg, az RRF 2.3.1 21 2022 00008 számú projekt támogatásával.

Kulcsszavak: súlyliziméter, evapotranszspiráció, vízhasznosítási hatékonyság, öntözésirányítás, csemegekukorica

REFERENCES

Allen, R. G., Pereira, L. S., Howell, T. A., & Jensen, M. E. (2011). Evapotranspiration information reporting: I. Factors governing measurement accuracy. *Agricultural Water Management, 98*(6), 899–920. https://doi.org/10.1016/j.agwat.2010.12.015

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). *Crop evapotranspiration: Guidelines for computing crop water requirements* (FAO Irrigation and Drainage Paper No. 56). Food and Agriculture Organization of the United Nations. https://www.fao.org/4/x0490e/x0490e00.htm

Antal, E. (1968). *Az öntözés előrejelzése meteorológiai adatok alapján* [Forecasting irrigation based on meteorological data] [Candidate dissertation]. Budapest. https://real-d.mtak.hu/989/1/D_3945_Antal_Emanuel.pdf

Báder, L. (2023). Magyarország vízmérlege és az éghajlatváltozás [Hungary's water balance and climate change]. *Hidrológiai Közlöny, 103*(1), 4–16. https://doi.org/10.59258/hk.10410

Bartholy, J., & Pongrácz, R. (2010). Analysis of precipitation conditions for the Carpathian Basin based on extreme indices in the 20th century and climate simulations for 2050 and 2100. *Physics and Chemistry of the Earth, 35*(1–2), 43–51. https://doi.org/10.1016/j.pce.2010.03.011

Blum, A. (2009). Effective use of water (EUW) and not water-use efficiency (WUE) is the target of crop yield improvement under drought stress. *Field Crops Research, 112*(2–3), 119–123. https://doi.org/10.1016/j.fcr.2009.03.009

Carr, M. K. V. (2013). Crop yield response to water. FAO Irrigation and Drainage Paper 66, by P. Steduto, T. C. Hsiao, E. Fereres, & D. Raes [Book review]. *Experimental Agriculture, 49*(2), 311. https://doi.org/10.1017/S0014479712001366

Evans, R. G., & Sadler, E. J. (2008). Methods and technologies to improve efficiency of water use. *Water Resources Research, 44*(W00E04), 1–15. https://doi.org/10.1029/2007WR006200

Evett, S. R., Schwartz, R. C., Howell, T. A., Baumhardt, R. L., & Copeland, K. S. (2012). Can weighing lysimeter ET represent surrounding field ET well enough to test flux station measurements of daily and sub-daily ET? *Advances in Water Resources, 50*, 79–90. https://doi.org/10.1016/j.advwatres.2012.07.023

FAO. (2002). *Deficit irrigation practices* (FAO Water Reports No. 22). Food and Agriculture Organization of the United Nations. https://www.fao.org/4/y3655e/y3655e00.htm

Fehér, Z. Z. (2019). *A Dél-Alföld talajvíz idősorainak nagy léptékű, geostatisztikai alapú modellezése* [Large-scale geostatistical modeling of groundwater time series in the Southern Great Plain] [Doctoral dissertation, University of Szeged]. https://doktori.bibl.u-szeged.hu/id/eprint/10122/

Fereres, E., & Soriano, M. A. (2006). Deficit irrigation for reducing agricultural water use. *Journal of Experimental Botany, 58*(2), 147–159. https://doi.org/10.1093/jxb/erl165

García y García, A., Guerra, L. C., & Hoogenboom, G. (2009). Water use and water use efficiency of sweet corn under different weather conditions and soil moisture regimes. *Agricultural Water Management, 96*(10), 1369–1376. https://doi.org/10.1016/j.agwat.2009.04.022

Geerts, S., & Raes, D. (2009). Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. *Agricultural Water Management, 96*(9), 1275–1284. https://doi.org/10.1016/j.agwat.2009.04.009

Groh, J., Vanderborght, J., Pütz, T., Vogel, H.-J., Gründling, R., Rupp, H., Rahmati, M., Sommer, M., Vereecken, H., & Gerke, H. H. (2020). Responses of soil water storage and crop water use efficiency to changing climatic conditions: A lysimeter-based space-for-time approach. *Hydrology and Earth System Sciences, 24*(3), 1211–1225. https://doi.org/10.5194/hess-24-1211-2020

Hannes, M., Wollschläger, U., Schrader, F., Durner, W., Gebler, S., Pütz, T., Fank, J., von Unold, G., & Vogel, H.-J. (2015). A comprehensive filtering scheme for high-resolution estimation of the water balance components from high-precision lysimeters. *Hydrology and Earth System Sciences, 19*(8), 3405–3418. https://doi.org/10.5194/hess-19-3405-2015

Hatfield, J. L., & Dold, C. (2019). Water-use efficiency: Advances and challenges in a changing climate. *Frontiers in Plant Science, 10*, 103. https://doi.org/10.3389/fpls.2019.00103

Howell, T. A. (2001). Enhancing water use efficiency in irrigated agriculture. *Agronomy Journal, 93*(2), 281–289. https://doi.org/10.2134/agronj2001.932281x

Intergovernmental Panel on Climate Change. (2021). *Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009157896

Irmak, S., Djaman, K., & Rudnick, D. R. (2016). Effect of full and limited irrigation amount and frequency on subsurface drip-irrigated maize evapotranspiration, yield, water use efficiency and yield response factors. *Irrigation Science, 34*(4), 271–286. https://doi.org/10.1007/s00271-016-0502-z

Jones, H. G. (2004). Irrigation scheduling: Advantages and pitfalls of plant-based methods. *Journal of Experimental Botany, 55*(407), 2427–2436. https://doi.org/10.1093/jxb/erh213

Leng, G., & Hall, J. (2019). Crop yield sensitivity of global major agricultural countries to droughts and the projected changes in the future. *Science of the Total Environment, 654*, 811–821. https://doi.org/10.1016/j.scitotenv.2018.10.434

Lobell, D. B., Bala, G., & Duffy, P. B. (2006). Biogeophysical impacts of cropland management changes on climate. *Geophysical Research Letters, 33*(6), L06708. https://doi.org/10.1029/2005GL025492

Magaia, E. (2017). Technologies for improved water use efficiency in small-scale maize production in a semi-arid region [Doctoral dissertation, Swedish University of Agricultural Sciences]. Acta Universitatis agriculturae Sueciae, 2017:53. https://pub.epsilon.slu.se/14362/1/Magaia_e_170524.pdf

Magyar, T., Fehér, Zs., Buday-Bódi, E., Tamás, J., & Nagy, A. (2023). Modelling of soil moisture and water fluxes in a maize field for the optimization of irrigation. *Computers and Electronics in Agriculture, 213*, 108159. https://doi.org/10.1016/j.compag.2023.108159

Nagy, J. (2010). A kukoricatermesztés jelene és jövője [The present and future of maize production]. *Növénytermelés, 59*(3), 85–111. https://doi.org/10.1556/novenyterm.59.2010.3.6

Pálfai, I. (2004). *Belvizek és aszályok Magyarországon: Hidrológiai tanulmányok* [Floods and droughts in Hungary: Hydrological studies]. KÖZDOK Kft. https://library.hungaricana.hu/hu/view/VizugyiKonyvek_179/?pg=0&layout=s

Pereira, L. S., Cordery, I., & Iacovides, I. (2012). Improved indicators of water use performance and productivity for sustainable water conservation and saving. *Agricultural Water Management, 108*, 39–51. https://doi.org/10.1016/j.agwat.2011.08.022

Porfirio, L. L., Newth, D., Finnigan, J. J., & Cai, Y. (2018). Economic shifts in agricultural production and trade due to climate change. *Palgrave Communications, 4*(1), 1. https://doi.org/10.1057/s41599-018-0164-y

Richards, R. A., & Townley-Smith, T. F. (1987). Variation in leaf area development and its effect on water use, yield and harvest index of droughted wheat. *Australian Journal of Agricultural Research, 38*(6), 983–992. https://doi.org/10.1071/AR9870983

Seneviratne, S. I., Nicholls, N., Easterling, D., Goodess, C. M., Kanae, S., Kossin, J., Luo, Y., Marengo, J., McInnes, K., Rahimi, M., Reichstein, M., Sorteberg, A., Vera, C., & Zhang, X. (2012). Changes in climate extremes and their impacts on the natural physical environment. In C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor, & P. M. Midgley (Eds.), *Managing the risks of extreme events and disasters to advance climate change adaptation* (pp. 109–230). Cambridge University Press. https://doi.org/10.1017/CBO9781139177245.006

Sinclair, T. R., Messina, C. D., Beatty, A., & Samples, M. (2010). Assessment across the United States of the benefits of altered soybean drought traits. *Agronomy Journal, 102*(2), 475–482. https://doi.org/10.2134/agronj2009.0195

Spinoni, J., Naumann, G., Vogt, J., & Barbosa, P. (2015). European drought climatologies and trends based on a multi-indicator approach. *Global and Planetary Change, 127*, 50–57. https://doi.org/10.1016/j.gloplacha.2015.01.012

Steduto, P., Hsiao, T. C., Raes, D., & Fereres, E. (2009). AquaCrop—The FAO crop model to simulate yield response to water: I. Concepts and underlying principles. *Agronomy Journal, 101*(3), 426–437. https://doi.org/10.2134/agronj2008.0139s

Szalókiné Zima, I. (2023). Effect of irrigation and fertiliser doses on sweet corn yield, water consumption and water utilization. *Agrokémia és Talajtan, 72*(1), 64–80. https://doi.org/10.1556/0088.2023.00135

Tamás, J., Nagy, A., & Németh, T. (2022). Risks of agricultural water management and opportunities to reduce them in V4 countries. *Scientia et Securitas, 2*(4), 459–467. https://doi.org/10.1556/112.2021.00064

Umwelt-Geräte-Technik GmbH. (n.d.-a). Lysimeter. https://ugt-online.de/en/topics/system-solutions/lysimeter

Umwelt-Geräte-Technik GmbH. (n.d.-b). UGT lysimeter station. https://ugt-online.de/en/solutions/ugt-lysimeter-station

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. *Journal of Climate, 23*(7), 1696–1718. https://doi.org/10.1175/2009JCLI2909.1

Zhang, X., Qin, W., Chen, S., Shao, L., & Sun, H. (2017). Responses of yield and WUE of winter wheat to water stress during the past three decades—A case study in the North China Plain. *Agricultural Water Management, 179*, 47–54. https://doi.org/10.1016/j.agwat.2016.05.004

Zsembeli, J., & Kovács, G. (2006). Liziméteres vízforgalmi vizsgálatok talaj–növény rendszerben [Lysimetric water balance investigations in the soil–plant system]. In I. Kalmár (Ed.), *Alföldi Tudományos Tájgazdálkodási Napok* (pp. 1–5). Szolnok College, Mezőtúr.

DOI: 10.17108/ActAgrOvar.2026.67.1.6