# Effect of Partial Root Zone Drying on Water Consumption and Water Use Efficiency of Sweet Corn Under Two Drip Irrigation types in Gypsiferous Soil

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## Abstract

A field experiment was conducted during the autumn season of 2025 at the Research Station of the Department of Soil and Water Resources Sciences / College of Agriculture / Tikrit University, to study the effect of partial root-zone drying (PRD) under two drip irrigation types (GR and T-Tape) on soil moisture content, crop water consumption (ETc), and water use efficiency (WUE) for Sweet Corn (Zea mays L. var. saccharata) that grown in a gypsiferous soil. The experiment was implemented by using a randomized complete block design (RCBD) in a factorial arrangement, comprising three irrigation regimes (full irrigation, alternate partial root-zone drying, and fixed partial root-zone drying) and two drip irrigation types, with three replications. The results showed that soil moisture content was concentrated near the dripper and in the surface layers, then gradually decreased with increasing depth and with distance from the water source. The full irrigation treatment achieved the highest moisture content and the widest wetting front, whereas fixed partial root-zone drying recorded the lowest moisture content, while alternate partial root-zone drying maintained a balanced moisture distribution within the root zone. The results indicated that the highest crop water consumption was recorded under the full irrigation treatment, reaching 703 mm in the GR type and 667 mm in the T-Tape type . In contrast, the partial root-zone drying treatments reduced water consumption and achieved irrigation water savings ranging from 33.71% to 39.54% compared to full irrigation. Furthermore, the partial root-zone drying treatments were superior in water use efficiency, with alternate partial root-zone drying attaining the highest average WUE of 1.287 kg $m^{-3}$. The GR type significantly outperformed the T-Tape type, and the interaction between the GR type and alternate partial root-zone drying recorded the highest WUE at 1.332 kg $m^{-3}$. The study findings confirm that the application of alternate partial root-zone drying combined with the GR type constitutes an effective strategy for improving moisture distribution within the root zone , thereby promoting sustainable management of water resources in gypsiferous soils.

**Keywords:** partial root zone,; Water Consumption ; Water Use Efficiency ; Corn ; Drip irrigation ; gypsiferous soil.

## Introduction

Water is among the most important natural resources upon which agricultural production depends. However, the continuous increase in water demand, coupled with declining water resources and the growing impacts of climate change, has necessitated the development of modern strategies for irrigation water management and the improvement of water use efficiency, particularly in arid and semi-arid regions (Jovanovic and Stikic.,2018). Drip irrigation is considered one of the most efficient irrigation types for water conservation, as it delivers water directly to the root zone in amounts commensurate with crop water requirements, thereby reducing losses due to evaporation and surface runoff, and contributing to higher productivity per unit of water used and improved water use efficiency (Farooq *et al*., 2022).The success of drip irrigation depends largely on the pattern of soil moisture distribution within the soil profile, as the shape of the wetting front and the extent of horizontal and vertical water spread are influenced by the system

type, emitter discharge rate, soil properties, and irrigation frequency (Skaggs *et al.,*2010). Uniform moisture distribution within the root zone enhances water and nutrient uptake and reduces water losses, whereas poor moisture distribution adversely affects plant growth and water use efficiency, especially in soils with high permeability such as gypsiferous soils (FAO, 2023). Partial root‑zone drying (PRD) is considered one of the modern techniques in irrigation water management, as it involves irrigating one part of the root system while allowing the other part to dry, either alternately or in a fixed manner. This induces physiological responses that reduce water loss without causing a significant reduction in productivity. Studies have shown that this technique contributes to lowering water consumption, improving water use efficiency, and reducing water losses, while maintaining plant growth and yield—making it one of the best alternatives in regions suffering from limited water resources (Slamini *et al*., 2022; Al-Kubaisi *et al*., 2023). It is evident that water use efficiency (WUE) and water consumption (ETc) are among the most important indicators used to evaluate the success of irrigation programs. Water use efficiency expresses the quantity of yield produced per unit of water consumed or applied, while water consumption reflects the amount of water used by the crop during the growing season. Studies have demonstrated that the application of PRD can significantly reduce water consumption while maintaining crop productivity, thereby increasing WUE compared to full irrigation, particularly when applied using drip irrigation types (Al-Kubaisi *et al*., 2022; Al-Kubaisi *et al*., 2023). Sweet Corn (Zea mays L. var. saccharata) is an important cash crop that requires precise management of irrigation water due to its sensitivity to water stress during various growth stages. This importance is amplified when it is grown in gypsiferous soils, which are characterized by high gypsum content, high leaching rates, and low water‑holding capacity. This makes moisture distribution within the root zone more complex and necessitates the adoption of highly efficient irrigation systems and modern strategies for water conservation (Al-Kubaisi *et al*., 2023).

The objective of this research is to identify the best irrigation method and system that achieves appropriate moisture distribution, reduces water consumption, and enhances water use efficiency under gypsiferous soil conditions.

This study aims to evaluate soil weathering processes in gypsiferous soils under arid and semi-arid conditions in Al-Shirqat District, Iraq, by analyzing major oxides and calculating chemical weathering indices. The study also seeks to assess the vertical variation of these properties within soil pedons and to understand their relationship with soil development and pedogenic processes.

## Material and Methods

A field experiment was conducted to study the effect of partial root‑zone drying (PRD) under two drip irrigation types on the growth and yield of Sweet Corn (Zea mays L. var. saccharata) under gypsiferous soil conditions during the autumn season of 2025 at the Research Station of the Department of Soil and Water Resources Sciences / College of Agriculture / Tikrit University, located at latitude 34°40.49′ N and longitude 43°39.01′ E, at an elevation of 129 m above sea level.

This study involved two factors. The first was partial root-zone irrigation, implemented via three methods: full irrigation on both sides of the root zone; alternate irrigation on both sides (applying half the irrigation volume to one side, then the other in the subsequent irrigation, and so on throughout the growing season); and

applying half the irrigation volume to only one side throughout the growing season.
The second factor involved the application of irrigation water using two types of drip irrigation systems: T-Tape and GR.
The experiment was conducted using a Randomized Complete Block Design (RCBD) with three replicates, and the results were analyzed using Duncan's test.
The soil of the study site belongs to the order of Aridisols (soils of arid and semi-arid regions) with weak development, according to the USDA Soil Taxonomy system. The experimental site is also characterized by flat topography. Soil samples were collected from the field at a depth of 0–0.3 m, air-dried, and then sieved through a 2-mm mesh sieve for the purpose of determining the initial physical and chemical properties of the soil, as shown in Table (1).

**Table 1. Some physical and chemical properties of the field soil before planting at the studied depth.**

| Property | Value | Unit |
|---|---|---|
| Sand | 615 | g $kg^{-1}$ |
| Silt | 258 | g $kg^{-1}$ |
| Clay | 127 | g $kg^{-1}$ |
| Soil Texture | Sandy Loam | — |
| Gypsum ($CaSO_4 \cdot 2H_2O$) | 17.1 | g $kg^{-1}$ |
| Calcium Carbonate ($CaCO_3$) | 91 | g $kg^{-1}$ |
| Electrical Conductivity (ECe) | 28.2 | dS $m^{-1}$ |
| pH | 7.22 | — |
| Bulk Density | 1.47 | Mg $m^{-3}$ |
| Particle Density | 2.65 | Mg $m^{-3}$ |
| Porosity | 44.52 | % |
| Volumetric Water Content at 1500 kPa (Permanent Wilting Point) | 17.2 | % |
| Volumetric Water Content at 33 kPa (Field Capacity) | 31.1 | % |
| Available Nitrogen (N) | 22.41 | mg $kg^{-1}$ |
| Available Phosphorus (P) | 5.19 | mg $kg^{-1}$ |
| Available Potassium (K) | 116 | mg $kg^{-1}$ |
| Cation Exchange Capacity (CEC) | 13.41 | cmol(+) $kg^{-1}$ |
| Calcium ($Ca^{2+}$) | 2.77 | mmol $L^{-1}$ |
| Magnesium ($Mg^{2+}$) | 6.12 | mmol $L^{-1}$ |
| Sodium ($Na^{+}$) | 5.48 | mmol $L^{-1}$ |
| Potassium ($K^{+}$) | 1.70 | mmol $L^{-1}$ |

Soil properties were estimated according to the following methods:

• Soil texture was determined according to the modified method of Pearson *et al*., (2016) specifically for gypsiferous soils.

Gypsum content was determined according to Richards (1954), by precipitation of gypsum using acetone.

Calcium carbonate ($CaCO_3$) was determined by the sodium hydroxide

titration method as described in FAO (1974).

Electrical conductivity (EC) was measured using an EC meter as described in Richards (1954).

• Hydrogen ion concentration (pH) was measured using a pH meter as described in Richards (1954).

• Bulk density was determined for the study site using the soil core sampler method (Black *et al*., 1965).

• Particle density was estimated using the relationship proposed by Al-Rustom (2010).

• Cation exchange capacity (CEC) was estimated according to the methylene blue method of Savant (1994).

• Porosity was calculated based on bulk density and particle density values (Hillel, 1980) using the following equation:

$$f = [1 - (\rho b / \rho s)] \times 100 \quad \ldots\ldots (1)$$

Where:

• f = porosity (%)

• ρb = bulk density (Mg $m^{-3}$)

• ρs = particle density (Mg $m^{-3}$)

• Available nitrogen was determined by extraction with 2 M potassium chloride (KCl) solution according to the method of Bremner and Mulvaney (1982). Available phosphorus and available potassium were determined by extraction with 1 N ammonium acetate ($NH_4OAc$) according to the method described by Pratt (1965).

1. Measurement and evaluation of emitter discharge

Emitter discharge was measured at an operating pressure of 100 kPa by collecting water for 5 minutes, then discharge was calculated according to the following equation (Hajim and Yassin, 1992):

$$q = V / t \quad \ldots\ldots (2)$$

Where:

• q = emitter discharge (L $ha^{-1}$)

• V = volume of collected water (L)

• t = collection time (h)

The average emitter discharge was calculated according to the following equation (Ismail, 2002):

$$\bar{q} = \Sigma q_i / n \quad \ldots\ldots (3)$$

Where:

• $\bar{q}$ = average discharge (L $ha^{-1}$)

• $q_i$ = individual emitter discharge (L $ha^{-1}$)

• n = number of emitters

Coefficient of variation (CV)

$$q_{var} = [(q_{max} - q_{min}) / q_{max}] \times 100 \quad \ldots\ldots (4)$$

This expresses the magnitude of variation between the highest and lowest emitter discharge rates, measured as a percentage (%).

Coefficient of uniformity (CU)

$$CU = 100 \times [1 - (\Sigma |x_i| / (m \times n))] \quad \ldots\ldots (5)$$

This expresses the evenness of water distribution among emitters, measured as a percentage (%).

Emission uniformity (EU)

$$EU = (q_{25\%} / \bar{q}) \times 100 \quad \ldots\ldots (6)$$

This expresses the uniformity of emitter discharge rates, measured as a percentage (%).

Soil moisture distribution and water movement within the soil were measured 24 hours after irrigation. Soil samples were taken at four horizontal distances from the emitter: 0, 10, 20, and 30 cm, and at three vertical depths below the emitter: 10, 20, and 30 cm. A small soil auger (Mini-Auger) with an internal diameter of 1.5 cm and length of 50 cm was used to collect soil samples from the designated locations.

Samples were dried in an electric oven at 70 °C until constant weight was achieved.

3. Actual crop water consumption (ETa)

The water balance equation was used as a direct method for calculating actual crop water consumption according to the following equation (Allen *et al*., 1998):

$(I + P + C) - (ETa + D + R) = \pm \Delta S$ …(7)

Where:

• I = applied irrigation water (mm)

• P = precipitation (mm)

• C = capillary rise (mm) – contribution of groundwater to irrigation

• ETa = actual evapotranspiration (mm)

• D = deep percolation (mm)

• R = surface runoff (mm)

• ±ΔS = change in soil moisture storage at the beginning and end of the season

Given that:

• R = 0 (since the land is flat and surface runoff is negligible)

• C = 0 (since groundwater is deep)

• D = 0 (since irrigation is applied after depletion – [text incomplete])

Therefore, the equation becomes:

$I + P = ETa \pm \Delta S$ …… (8)

Field water use efficiency was calculated using the following equation (Allen *et al*., 1998):

$WUE = Y / Wa$ …… (9)

Where:

• WUE = field water use efficiency (kg $m^{-3}$)

• Y = grain yield (kg $ha^{-1}$)

• Wa = amount of water applied in irrigation ($m^3$ $ha^{-1}$).

## RESULT AND DISCUSSION

**- Evaluation of drip irrigation system performance**

**- Evaluation of the hydraulic performance of the two drip irrigation types (GR and T-Tape)**

The evaluation of hydraulic performance revealed differences in the efficiency of the GR and T-Tape types depending on the irrigation treatments and growth stages, as discharge rates, coefficient of uniformity, coefficient of variation, and emission uniformity were affected by operating duration and clogging resulting from the accumulation of debris and salts within the emitters (Al-Saadi *et al*., 2024).

**- Effect of discharge rate and system type on actual discharge rate**

The results in Table (2) showed that the GR system was superior in actual discharge rate compared to the T-Tape system across the different study stages. Discharge gradually decreased from the pre-planting stage to the flowering stage in both systems. This is attributed to the accumulation of suspended solids and salt precipitates with continued operation (Al-Obaidi, 2022; Al-Jumaili, 2021). The superiority of GR is attributed to its wider flow passages and lower susceptibility to clogging, whereas the narrow passages in T-Tape increase the likelihood of debris accumulation and reduced discharge (Al-Mula, 2024).

**- Effect of discharge rate and system type on the coefficient of uniformity**

The results in Table (2) showed that the coefficient of uniformity was high at the beginning of the experiment in both systems, then decreased as the growth stages advanced due to operating conditions and the accumulation of debris. The GR system exhibited better stability in the coefficient of uniformity during the later stages, particularly at discharge rate I1, compared to T-Tape, owing to its greater resistance to clogging and its ability to maintain uniform water distribution (Saleh, 2023;; Zhou *et al*., 2025).

**- Effect of discharge rate and system type on the coefficient of variation**

The results showed that the coefficient of variation generally increased with decreasing discharge, and also increased as the season progressed due to the accumulation of debris and salts within the systems. Both GR and T‑Tape recorded increases in CV values during the flowering stage; however, the overall hydraulic performance demonstrated that the GR system had a better ability to maintain discharge stability and uniformity (Li *et al*., 2024; Al‑Rifai, 2024).

**- Effect of discharge rate and system type on emission uniformity**

The results showed that T‑Tape was superior in some emission uniformity values before planting, but GR demonstrated better stability after planting, particularly during the flowering stage. The emission uniformity value at I1 in GR reached approximately 95.68%, compared to 88.64% in T‑Tape. The decline in T‑Tape uniformity is attributed to debris accumulation and narrow flow passages, accompanied by a reduction in pressure and flow along the irrigation laterals (Steele, 2015).

**Table 2. Irrigation system evaluation indicators**

| Stage & System | Irrigation Method | Discharge Rate (L/h) | Uniformity Coefficient (%) | Variation Ratio (%) | Emission Uniformity (%) |
|---|---|---|---|---|---|
| Pre-planting Stage (GR) | I1 | 7.49a | 98.84a | 4.50c | 97.64a |
| Pre-planting Stage (GR) | I2 | 3.63b | 96.61c | 10.69b | 95.53a |
| Pre-planting Stage (GR) | I3 | 1.74c | 93.49b | 18.75a | 89.65b |
| Pre-planting Stage (T-Tape) | I1 | 4.25a | 98.34a | 5.11c | 97.45a |
| Pre-planting Stage (T-Tape) | I2 | 2.11b | 96.74b | 8.43b | 95.88b |
| Pre-planting Stage (T-Tape) | I3 | 0.98c | 96.54b | 10.37a | 95.12b |
| Vegetative Growth Stage (GR) | I1 | 7.11a | 97.63a | 5.01c | 96.17a |
| Vegetative Growth Stage (GR) | I2 | 3.58b | 95.32a | 11.12b | 94.60c |
| Vegetative Growth Stage (GR) | I3 | 1.65c | 91.64b | 18.94a | 88.95b |
| Vegetative Growth Stage (T-Tape) | I1 | 3.95a | 94.22c | 5.45c | 92.11c |
| Vegetative Growth Stage (T-Tape) | I2 | 1.94b | 95.15b | 9.64b | 93.42b |
| Vegetative Growth Stage (T-Tape) | I3 | 0.83c | 96.56a | 11.13a | 94.88a |

**- Effect on soil moisture content**

**GR drip irrigation system**

The results of soil moisture distribution in the GR system , table 3 showed that the

highest moisture values were concentrated near the emitter and in the surface layers, then gradually decreased with increasing depth and distance from the water source. This is attributed to the uniform emitter discharge and the effect of the high permeability of the gypsiferous soil on water movement within the profile (Pereira *et al*., 2022).

The full irrigation treatment (I1) showed the highest moisture content and the widest wetting front, as a result of meeting the full crop water requirements, which improved water spread within the root zone (Fereres and Soriano, 2021).

The alternate partial root-zone drying treatment (I2) ranked second, maintaining a balanced moisture distribution within the root zone while reducing the amount of water used, as a result of alternating irrigation between the two sides of the root system (Kang and Zhang, 2004).

The fixed partial root-zone drying treatment (I3) recorded the lowest moisture content and the smallest wetting front, due to the reduced amount of water applied and the high permeability of the gypsiferous soil (FAO, 2023).

**T-Tape drip irrigation type**

The results of the T-Tape Type in Table 3 showed a more uniform pattern of moisture distribution, with the highest moisture values concentrated near the emitter and then gradually decreasing with depth and distance from the water source, which contributed to the formation of a regular wetting front within the root zone (Pereira *et al*., 2022).

The full irrigation treatment (I1) achieved the highest moisture content and the widest wetting front, as a result of meeting the full crop water requirements and improving soil water storage (Fereres and Soriano, 2021).

The alternate partial root-zone drying treatment (I2) showed the second-highest values, providing appropriate moisture distribution while reducing irrigation water amounts and maintaining water uptake efficiency (Kang and Zhang, 2004).

The fixed partial root-zone drying treatment (I3) recorded the lowest moisture content with a noticeable contraction of the wetting front, due to the reduced amount of water applied and the high permeability of the gypsiferous soil (FAO, 2023).

**Table 3. Humidity distribution around the drippers**

| Irrigation System and Regime | Depth (cm) | Horizontal Distance (cm) 0 | Horizontal Distance (cm) 5 | Horizontal Distance (cm) 10 | Horizontal Distance (cm) 20 |
|---|---|---|---|---|---|
| Full irrigation + GR + system | 10 | 26.40 | 23.10 | 19.45 | 16.20 |
| | 20 | 24.15 | 21.05 | 18.20 | 15.10 |
| | 30 | 22.10 | 19.80 | 16.15 | 13.05 |
| Fixed partial irrigation + GR + system | 10 | 22.10 | 17.40 | 13.25 | 9.80 |
| | 20 | 19.80 | 15.20 | 11.40 | 7.65 |
| | 30 | 16.50 | 12.10 | 9.05 | 5.20 |
| Alternate partial irrigation + GR + system | 10 | 25.80 | 24.95 | 23.10 | 21.40 |
| | 20 | 23.50 | 22.80 | 21.15 | 19.60 |
| | 30 | 21.20 | 20.50 | 19.00 | 17.35 |
| Full irrigation + T-Tape + system | 10 | 24.10 | 20.85 | 17.30 | 14.10 |
| | 20 | 22.05 | 18.50 | 15.40 | 12.15 |
| | 30 | 19.30 | 16.10 | 13.05 | 9.90 |

| | | | | | |
|---|---|---|---|---|---|
| Fixed partial irrigation + T-Tape + system | 10 | 20.80 | 15.10 | 11.05 | 7.20 |
| | 20 | 18.40 | 13.00 | 9.20 | 5.15 |
| | 30 | 15.15 | 10.35 | 7.00 | 3.40 |
| Alternate partial irrigation + T-Tape + system | 10 | 23.50 | 22.15 | 20.40 | 18.50 |
| | 20 | 21.10 | 19.80 | 18.25 | 16.10 |
| | 30 | 18.90 | 17.40 | 15.90 | 14.05 |

**- Crop water consumption (ETa) of Sweet Corn**

The results in Table 4 showed that the crop water consumption of Sweet Corn gradually increased with advancing growth stages. It was low during the germination stage, then increased during the vegetative growth stage to reach its highest values, and remained high during the flowering stage, then decreased during the grain filling and maturation stage due to the completion of plant growth and the reduction in its physiological and water requirements, as well as the influence of prevailing climatic conditions during the later stages of the season (Zhou *et al*., 2025; Al-Obaidi, 2022).

The full irrigation treatment (I1) recorded the highest water consumption, followed by the alternate partial root-zone drying treatment (I2), while the fixed partial root-zone drying treatment (I3) achieved the lowest water consumption. This confirms the role of partial root-zone drying in reducing the amount of water consumed while maintaining crop productivity within acceptable limits (Liu *et al*., 2026).

Regarding the irrigation systems, the GR Type recorded higher water consumption compared to the T-Tape Type. This is attributed to its high hydraulic efficiency and uniform emitter discharge, which maintained uniform water distribution and reduced clogging during the growing season. The application of alternate partial root-zone drying (I2) also contributed to achieving greater water savings compared to fixed partial root-zone drying, as a result of improving water use efficiency and reducing transpiration losses by stimulating the plant's physiological response (Mustafa *et al*., 2025; Al-Mula, 2024).

**Table 4. Water consumption of sweet corn crop mm season$^{-1}$**

| Treatments | Number of irrigations | Emergence | Vegetative growth | Flowering | Grain formation | Rainfall (mm) | Total irrigation water depth (mm) | Water saving (%) |
|---|---|---|---|---|---|---|---|---|
| $I_1$ GR | 47 | 222 | 283 | 103 | 95 | 0 | 703 | – |
| $I_2$ GR | 47 | 219 | 135 | 55 | 47 | 0 | 456 | 35.13 |
| $I_3$ GR | 47 | 217 | 142 | 58 | 49 | 0 | 466 | 33.71 |
| $I_1$ T-Tab | 47 | 208 | 271 | 98 | 90 | 0 | 667 | 5.12 |
| $I_2$ T-Tab | 47 | 205 | 129 | 46 | 42 | 0 | 422 | 38.54 |
| $I_3$ T-Tab | 47 | 204 | 136 | 50 | 45 | 0 | 435 | 39.54 |

**- Water use efficiency (WUE) of sweet corn**

The results in Table 5 showed a significant effect of irrigation method, irrigation system, and their interaction on the water use efficiency of Sweet Corn. The alternate partial root-zone drying treatment (I2) achieved the highest water use efficiency, followed by the fixed partial root-zone drying treatment (I3), while the full irrigation treatment (I1) showed the lowest efficiency. This is attributed to the fact that

alternate partial root-zone drying reduces the amount of water applied while maintaining crop productivity, thereby increasing the quantity of yield produced per unit of water used (Elshamly *et al*., 2024).

The GR system significantly outperformed the T-Tape Type in water use efficiency, as a result of its efficient distribution of irrigation water within the root zone, which improved water and nutrient uptake and reduced water losses, thereby increasing the quantity of yield produced per unit of water applied (FAO, 2023).

Regarding the interaction, the combination of the GR system with the alternate partial root-zone drying treatment (GR × I2) achieved the highest water use efficiency, while the combination of the T-Tape system with the full irrigation treatment (T-Tape × I1) recorded the lowest efficiency. This is attributed to the fact that combining the more efficient irrigation system with alternate partial root-zone drying improved water utilization and reduced losses while maintaining crop productivity (Al-Jumaili., 2023).

**Table 5. Water use efficiency for sweet corn Kg $m^{-3}$**

| Irrigation method | GR | T-Tab | Mean |
|---|---|---|---|
| $I_1$ | 0.968 c | 0.930 d | 0.949 c |
| $I_2$ | 1.352 a | 1.241 b | 1.287 a |
| $I_3$ | 1.316 a | 1.138 c | 1.227 b |
| Mean | 1.205 a | 1.103 b | – |

## Conclusion

• Partial root-zone drying (PRD) effectively reduced crop water consumption and achieved water savings ranging from 33.71% to 39.54% compared to full irrigation.

• Alternate partial root-zone drying (I2) achieved the highest water use efficiency, with an average of 1.287 kg $m^{-3}$.

• The GR Type outperformed the T-Tape Type in water use efficiency and hydraulic performance.

• The interaction (GR × I2) achieved the highest water use efficiency, reaching 1.332 kg $m^{-3}$, with balanced moisture distribution within the root zone.

• Alternate partial root-zone drying combined with the GR Type is considered the optimal approach under the conditions of this study for water conservation, improving moisture distribution, and enhancing water use efficiency in gypsiferous soils.

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## Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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## Author Contributions

The first and second authors contributed to writing the original draft of the manuscript, as well as reviewing and editing the final version. Both authors have read and approved the final manuscript and agreed to its submission.

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