# The relationship between Soil Sorptivity, gypsum application method and water irrigation salinity levels

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## Abstract

A laboratory experiment was conducted in the laboratories of the College of Agriculture at the University of Anbar To study the effect of soil gypsum content, water salinity levels, and application method (continuous and intermittent water addition) on the soil sorptivity values. The first factor involved three levels of gypsum soil, namely 9, 19.7 and 46.3%. A plastic transparent column of 40 cm in length was used to be filled with gypsum soil column (30 cm in height). The soil was packed with bulk density approximately equal to the field bulk density. The second factor included three levels of saline water, namely 2, 4 and 8 dS $m^{-1}$. The saline water was supplied in two methods, namely continuous and intermittent. The sorptivity was measured using the relationship between the cumulative infiltration and the root of time. The results showed that the sorptivity increased with the increase in gypsum content. Where the highest sorptivity value reached 2.078 cm $min^{-1/2}$ at gypsum content of 46.3%. While the lowest value reached 0.933 cm $min^{-1/2}$ at the gypsum content 9%. Unlike the gypsum content, the water salinity levels, led to decrease the soil sorptivity with the increase in salinity levels, where the highest sorptivity reached 0.933 cm $min^{-1/2}$ at a salinity level of 2 $dSm^{-1}$. While the lowest sorptivity reached 0.408 cm $min^{-1/2}$ at a salinity level of 8 dS $m^{-1}$. The soil sorptivity was slightly defer under effect of addition method, where the highest value reached 0.933 $cm\,min^{-1/2}$for the continuous addition method and the lowest value 0.805 cm $min^{-1/2}$ in the intermittent addition method.

**Keywords:** Gypsum content, Sorptivity, Saline water, Application method.

## Introduction

In many regions of the world, gypsum soils occupy a large area of land. The importance of studying gypsum soil in Iraq comes from the fact that it constitutes 20% of the Iraq total area. smaller portion of the gypsum soils are utilized as agricultural lands, where irrigation water is available (1). Gypsum soil suffers from many problems related to its physical and chemical properties due to the high solubility of gypsum in water (2.6 g $L^{-1}$), which causes potential problems with dissolution piping, primarily in response to irrigation. Additionally, gypsum soils also have characteristically restricted water and nutrient retention. Soil with high gypsum content, changes the chemical and physical properties of both soil and water. However, soil with moderate gypsum content can prevent or reduce the occurrence of some negative soil processes, at the same time, gypsum can limit or restrict the use of soil for both agricultural and engineering purposes if it is present in relatively high

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quantities (2). In this regard, many studies have indicated that soil with high gypsum content leads to changes the soil physical properties, including the soil sorptivity. (3) defined sorptivity as a physical property of the porous medium that is fairly similar to permeability, it is a measure of the soil's ability to absorb or lose water by capillary action, and it is related to the properties of the porous medium. Soil sorptivity can be affected by the soil gypsum content. Where increasing soil gypsum content increases the rate of water sorptivity. In study conducted by (4) noted that the sorptivity values that measured from the wetting speed of soil aggregates according to the method of (5) increased with increasing the soil gypsum content. Similarly, (6) noted that the sorptivity values increased with the increase in the soil gypsum content, where the high sorptivity values were observed at high soil gypsum content. Similarly, water movement increases in gypsum soils with the increase in the soil gypsum content. The gypsum content of the soil affects the salt distribution in the soil (7). Many studies have indicated that the behavior of gypsum soils varies depending on the irrigation water used. A study conducted by Samir indicated a difference in water movement in gypsum soil irrigated with river water and well water, where the river water works to dissolve the gypsum to a greater degree, consequently change the soil physical properties in terms of structure and soil hydraulic properties while well water reduced the solubility of gypsum. Consequently, has a limited effect on the soil properties (8). Similarly, (6) studied the two types of water (river water and well water), and pointed that the use of river water led to the dissolution of gypsum and increased the soil wettability compared to well water, while the use of well water improved the water transport properties by reducing the gypsum solubility. Regarding the addition method, there are studies indicating that adding water intermittently increases water distribution in the soil (9). The current study aimed to determine the effect of soil gypsum content, the water salinity levels, and water application method (continuous and intermittent water addition) on the soil sorptivity values.

## Material and Methods

### Prepare samples:

A two factorial laboratory experiment was conducted according to completely randomized design (CRD). The first factor involved three levels of gypsum soil, namely 9, 19.7 and 46.3% symbolled as G1, G2 and G3 respectively. The second factor included three levels of saline water (well water), namely 2, 4 and 8 $dSm^{-1}$ symbolled as S1, S2 and S3 respectively. The gypsum soil was collected from an area with gypsum soil in Jazeerah Al-Karma region (Latitude: 33° 32′ 26.1″ N and Longitude: 43° 57′ 30.2″ E). In the study area, a soil profile was prepared with 1 m depth, the gypsum content was measured at three depths, namely 20, 40 and 70 cm. Soil samples were air-dried, ground, and passed through a 2-mm sieve. Some physical and chemical properties of the study site were determined as shown in Table 1 and Table 2.

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**Table 1. Some soil Physical properties**

| Unit | G3 | G2 | G1 | Parameter |
|---|---|---|---|---|
| - | - | | Loam | Texture Soil |
| g $kg^{-1}$ | - | - | 442 | Sand |
| g $kg^{-1}$ | - | - | 332 | Silt |
| g $kg^{-1}$ | - | - | 226 | Clay |
| Mg $m^{-3}$ | 1.23 | - | 1.36 | Soil Dry Bulk density |
| Mg $m^{-3}$ | 2.50 | 1.3 | 2.62 | Soil particles density |
| % | 0.508 | 2.55 | 0.48 | porosity |
| cm $min^{-1}$ | 0.0689 | 0.49 | 0.0418 | Soil hydraulic conductivity |
| $cm^3$ $cm^{-3}$ | 0.69 | 0.0566 | 0.46 | Volumetric moisture at saturation |
| $cm^3$ $cm^{-3}$ | 0.20 | 0.51 | 0.25 | Volumetric moisture at 33 Kpa |
| $cm^3$ $cm^{-3}$ | 0.07 | 0.24 | 0.09 | Volumetric moisture at 500 Kpa |

G1, G2 and G3 is the gypsum soil content with the depth.

**Table 2. Some soil chemical properties**

| Unit | G3 | G2 | G1 | Parameter |
|---|---|---|---|---|
| - | 7.87 | 7.82 | 7.43 | pH |
| dS $m^{-1}$ | 2.7 | 2.04 | 1.92 | Electrical conductivity (EC) |
| g $kg^{-1}$ | 463 | 197 | 90 | $CaSo_4$ |
| g $kg^{-1}$ | 139 | 142 | 164 | $CaCo_3$ |
| g $kg^{-1}$ | 7.80 | 13.40 | 15.30 | Organic matter |
| mg $kg^{-1}$ | 1.70 | 2.00 | 2.90 | $Na^+$ |
| mg $kg^{-1}$ | 1.00 | 1.70 | 2.60 | $K^+$ |
| mg $kg^{-1}$ | 389.7 | 285.70 | 136.4 | $Ca^{++}$ |
| mg $kg^{-1}$ | 5.40 | 6.20 | 7.20 | $Mg^{++}$ |
| mg $kg^{-1}$ | 7.40 | 5.30 | 3.10 | $Cl^-$ |
| mg $kg^{-1}$ | 23.70 | 16.40 | 13.50 | $SO_4^=$ |

G1, G2 and G3 is the gypsum soil content with the depth.

**Table 3. Some characteristics of the considered water**

| Unit | S3 | S2 | S1 | Parameter |
|---|---|---|---|---|
| dS $m^{-1}$ | 8.87 | 4.71 | 2.63 | EC |
| | 8.33 | 7.85 | 7.62 | pH |
| mmol $L^{-1}$ | 72.12 | 38.21 | 20.51 | $Na^+$ |
| mmol $L^{-1}$ | 0.16 | 0.11 | 0.09 | $K^+$ |
| mmol $L^{-1}$ | 14.2 | 8.2 | 5.2 | $Ca^{++}$ |
| mmol $L^{-1}$ | 12.2 | 6.9 | 4 | $SO_4^{-2}$ |
| mmol $L^{-1}$ | 4.02 | 2.06 | 1.4 | Mg |
| | 40.5 | 26.64 | 20.61 | SAR |
| | C5S4 | C4S4 | C3S3 | *Water class |

The water was classified according to USDA 1954 (10)*

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The saline water was supplied in two methods, namely continuous method symbolled as A1. The saline water was added either in a single dose, where the entire required volume was added continuously until it reached the end of the column. and intermittent method symbolled as A2. The required water volume was added intermittently, unlike continuous addition, so that the addition time is equal to the cutting time for all transactions. The supplied water was determined based on the pore space volume of the soil column. When the water reaches the bottom of the column, its flow was stopped using a valve to control opening and closing .

Preparing soil columns

Transparent plastic cylindrical columns with a length of 0.40 m and an internal diameter of 0.05 m were used to prepare soil columns with a length of 0.30 m, Figure 2. A layer of glass wool was placed at the bottom of the column, followed by a layer of washed gravel with diameters ranging from 0.0002 to 0.0004 m used as a filter. A base with a diameter slightly larger than the outer diameter of the column was placed at the end of the column, and a small tube with a diameter of 0.01 m was embedded inside it to collect the leachate during the leaching process. Soil columns were prepared by filling each group of columns (replicate) with air-dried soil samples passed through 2 mm diameter sieve with gypsum content of 9, 19.7 and 46.3%. A total of 18 columns were prepared for each gypsum level by placing the soil sample in another column of smaller diameter. This column was pulled slightly upwards using a rotational technique. The outer wall of the column was gently tapped with a rubber hammer while simultaneously pulling the inner column up and down (11). The columns are moistened from the bottom using capillary action using distilled water to maintain uniform moisture distribution throughout the column. The columns were fixed on an aluminum stand with rings of diameter equal to the diameter of the pipe to facilitate the pipes support. The percentage of gypsum was estimated using the acetone method described in (12), the bulk density of the soil using the Core method, and the concentration of cations and anions were measured according to (13). The electrical conductivity and degree of soil reaction were measured using an electric conductivity meter and a pH meter as described in (14.(

Sorptivity

Philipp equation was used to calculate the vertical flow (Eq. 1), the relationship between the vertical infiltration (cm) and time (minute) was plotted. Solver function in Excel was used to estimate the sorptivity values, the sorptivity was estimated according to (15) using the first 3 minutes of infiltration data. Water was added to the surface of each column using custom-designed device. This device allowed for precise calculation of the amount of water absorbed and enabled controlled water application. Additionally, the device maintained a constant water head of 0.01 m above the soil surface. Figure (1) shows the parts of the device

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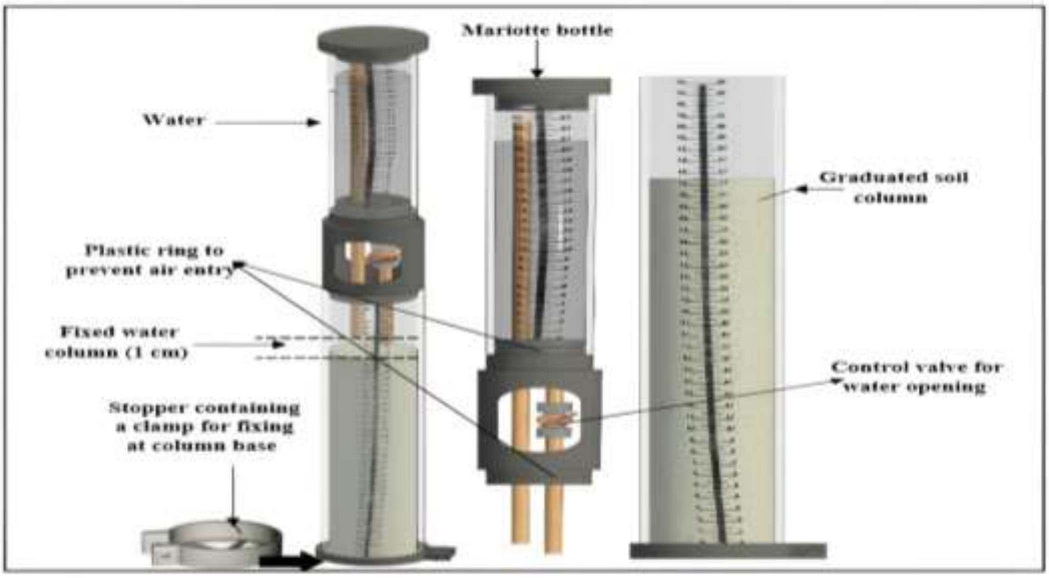


**Fig 1**. shows the parts of the device used in the experiment to control the addition of water.

## Results and Discussion

### Effect of gypsum content on sorptivity values

Strong linearity relationship was observed between cumulative infiltration (I) and the square root of time (t) Fig 2. where the slope of the fitted line represents the sorptivity (S) (3). The figure also shows that higher sorptivity values were observed as a result of increasing the soil gypsum content. After the first three minutes, the soil sorptivity values were 0.933, 1.465, and 2.078 cm. $min^{-1/2}$ for the soils with 9%, 19.7%, and 46% gypsum content, respectively. The evident indicated a direct positive correlation between soil gypsum content and the absorbed water. Probably due to gypsum high solubility, which enhances the soil infiltration properties, accordingly sorptivity increases as gypsum content increased. The dissolution of gypsum expands the effective cross-sectional area for water flow and promotes greater water movement by increasing the number of available water-conducting pores (11); (16). Additionally, under normal temperature and pressure conditions, gypsum has a relatively high solubility of 2.6 g/L, which makes it easier for new flow paths to form within the soil profile. (17) pointed out that gypsum's affinity for water improves infiltration even more, especially in soils with higher gypsum concentrations.

### Effect of water salinity levels and addition method on sorptivity values

The obtained results showed a noticeable decrease in the sorptivity values linked with

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increasing the salinity level of the considered soils, Fig 3, 4 and 5, where Fig 3 shows the effect of water salinity levels in soil with a gypsum content of 9%, where the highest sorptivity value was observed at a time 3 minutes reached 0.933 $cm\,min^{-1/2}$at a salinity level of 2 dS $m^{-1}$ while the lowest soil sorptivity value was 0.408 $cm\,min^{-1/2}$ at a salinity level of 8 dS $m^{-1}$. The sorptivity reduction can be attributed to the increased affinity between low-salinity water and the gypsum content, which causes an increase in the solubility of gypsum and thus an increase in water movement and sorptivity. Moreover, affinity decreases with increasing water salinity levels, leading to a reduction in gypsum solubility, which in turn reduces water movement and reduces soil sorptivity values. Also, saline water typically contains high concentrations of calcium and sulfate ions, consequently intensifying the common-ion effect (18), and this is related to the solubility product constant (Ksp) (19) and (17). Regarding the addition method, the sorptivity values increased with the continuous addition method while decreased with the intermittent addition method, in this context, the soil sorptivity reached to 0.933, 0.739 and 0.600 $cm.min^{-1/2}$ after 3 minutes for water salinity levels of 2, 4 and 8 dSm-1respectively, for the continuous addition method. Increasing the sorptivity can be attributed to the fact that under the intermittent method of water application, the total volume of added water is reduced, thereby diminishing the influence of water pressure that typically facilitates water movement. Conversely, the continuous addition of water results in constant water pressure, which increases the movement of water through the soil profile (faster infiltration). In addition, a reduction in soil matric potential may occur following water cessation, potentially allowing soil particles to aggregate after the initial application, which subsequently limits vertical water flow. The lower rate of soil water sorptivity observed under intermittent addition further supports this explanation, whereas continuous addition enhances sorptivity. These findings are consistent with those reported by (20). The soil sorptivity values increased to 1.465$cm\,min^{-1/2}$ at a time of 3 minutes under effect of 19.7% gypsum content, salinity level of 2 dS $m^{-1}$and continuous addition method Fig 4. While the lowest value recorded was 0.917 cm $min^{-1/2}$ under 8 dS $m^{-1}$ salinity and intermittent addition method. Comparable patterns were observed at salinity levels of 2, 4, and 8 dS $m^{-1}$, the sorptivity values under continuous addition were 1.465, 1.140, and 1.099 cm $min^{-1/2}$, respectively. On the other hand, the corresponding values under intermittent addition were 1.267, 1.050, and 0.917 cm $min^{-1/2}$. Higher sorptivity values were obtained by increasing the gypsum content to 46.3% Fig 5. The lowest value was 1.085 cm $min^{-1/2}$ at 8 dS $m^{-1}$ salinity with intermittent addition. The increase in the concentrations of calcium or sulfate ions, or more precisely, the increase in the ionic activity of either ion in groundwater helps to compensate for the solubility product (Ksp = ($Ca^{++}$) ($So4^{=}$) =$2.5x10^{-5}$) thereby decreasing gypsum solubility in order to maintain equilibrium, given that the KspK_{sp}Ksp value remains constant. Alternatively, the solubility of gypsum may also be described by a first-order kinetic equation (21). while the highest value was 2.078 cm $min^{-1/2}$ at 3 minutes under 2 dS $m^{-1}$ salinity and continuous water addition. Once more, for salinity levels of 2, 4, and 8 dS $m^{-1}$, the continuous addition method

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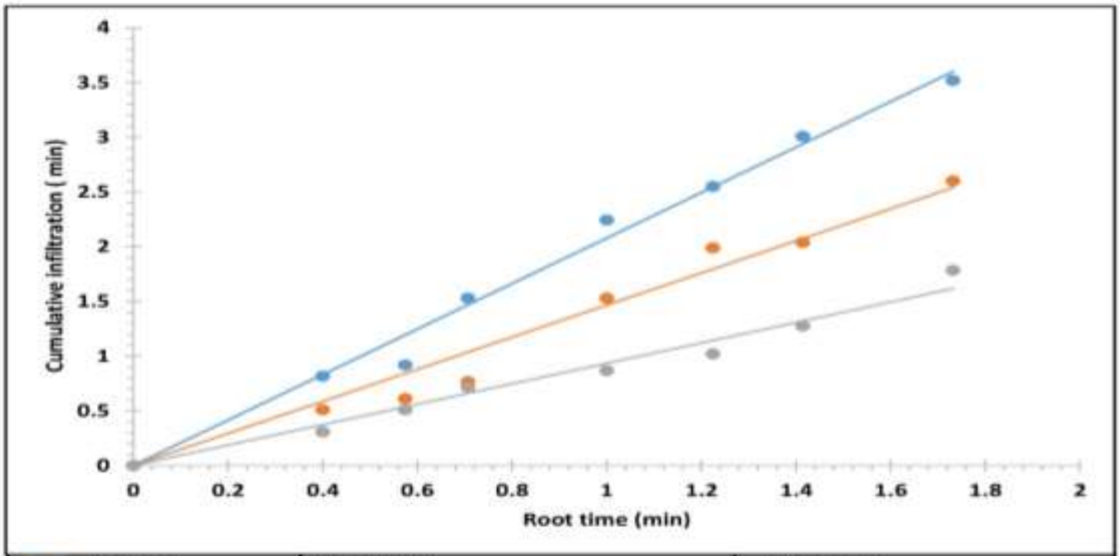
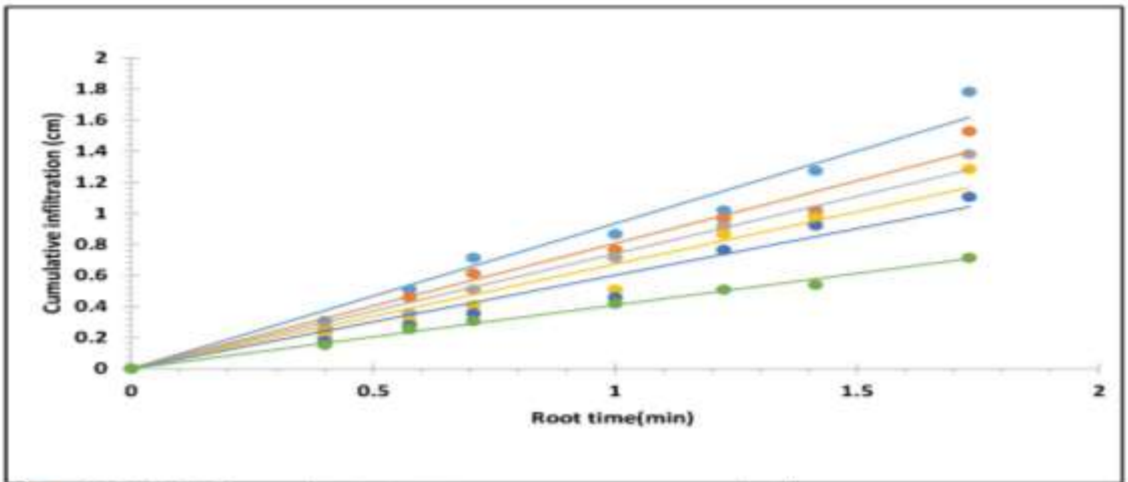
consistently yielded higher sorptivity values (2.078, 1.671, and 1.201 cm min⁻ $^{1/2}$, respectively) compared to 1.792, 1.480, and 1.085 cm min⁻ $^{1/2}$, respectively for intermittent addition.




| | | |
|---|---|---|
| G2S1A1 | Y= 2.078X | $R^2$=0.9884 |
| C3S1A1 | Y= 1.4658X | $R^2$= 0.9693 |
| G1S1A1 | Y= 0.9336X | $R^2$= 0.9739 |

Figure 2. Effect of gypsum content on sorptivity values.




| | | |
|---|---|---|
| C1S1A1 | Y= 0.9336X | $R^2$=0.9739 |
| G1S1A2 | Y= 0.8055X | $R^2$= 0.9749 |
| G1S2A1 | Y= 0.7394X | $R^2$= 0.9832 |
| G1S2A2 | Y=0.6726X | $R^2$= 0.9557 |
| G1S3A1 | Y= 0.6007X | $R^2$= 0. 9584 |
| G1S3A2 | Y= 0.4082X | $R^2$= 0.9935 |

Figure 3. Effect of water salinity levels and addition method on the soil sorptivity with a gypsum content of 9.%

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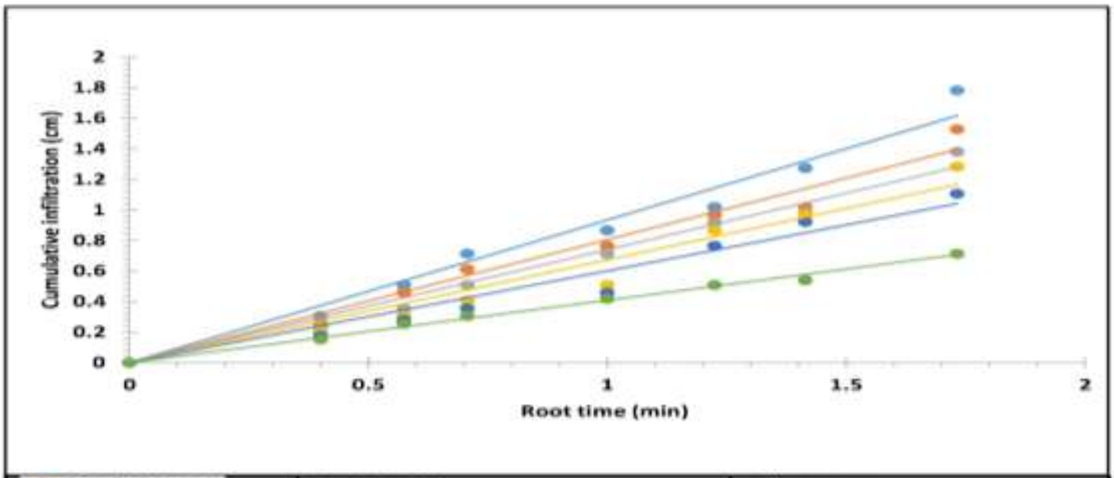
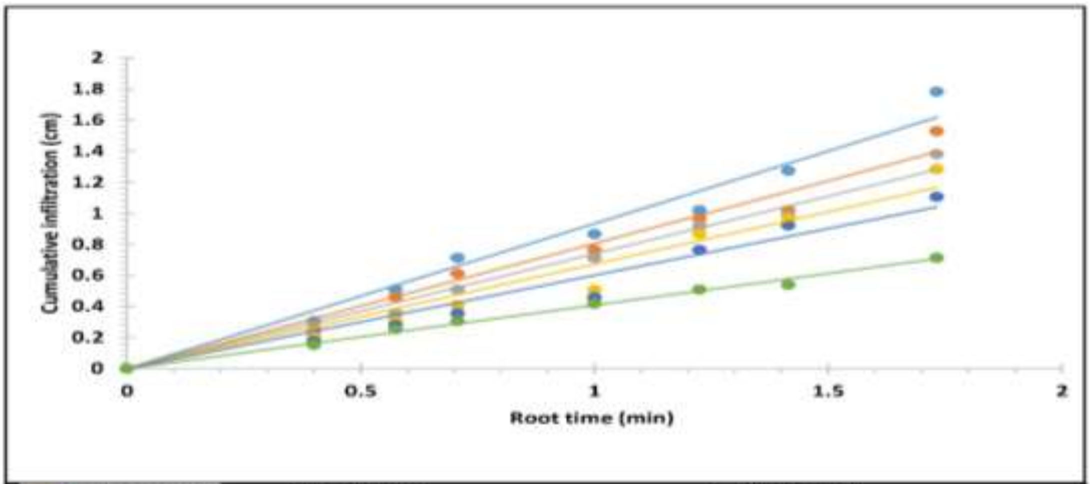



| | | |
|---|---|---|
| C1S1A1 | Y= 1.4658X | $R^2$=0.9693 |
| G1S1A2 | Y= 1.2675X | $R^2$= 9373 |
| G1S2A1 | Y= 1.402X | $R^2$= 0.9323 |
| G1S2A2 | Y= 1.0526X | $R^2$= 0.9205 |
| G1S3A1 | Y= 1.0992X | $R^2$= 0. 9293 |
| G1S3A2 | Y= 0.9174X | $R^2$= 0.9263 |

Figure 4. Effect of water salinity levels and addition method on the soil sorptivity with a gypsum content of 19.7%.




| | | |
|---|---|---|
| C1S1A1 | Y= 2.078X | $R^2$=0.9884 |
| G1S1A2 | Y= 1.7922X | $R^2$= 0.976 |
| G1S2A1 | Y= 1.6718X | $R^2$= 0.9614 |
| G1S2A2 | Y= 1.4808X | $R^2$= 0.9646 |
| G1S3A1 | Y=1.2014 X | $R^2$= 0. 9749 |
| G1S3A2 | Y= 1.0856X | $R^2$= 0.9706 |

Figure 5. Effect of water salinity levels and addition method on the soil sorptivity with a gypsum content of 46.%

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## Conclusion

The study results showed that the water salinity level and saline application method clearly affected the gypsum soil sorptivity. The results showed a decrease in soil sorptivity with increasing water salinity at all gypsum levels in the study (9%, 19.7%, and 46.3%). The sorptivity reduction may be due to the decrease in gypsum solubility due to the common-ion effect and ionic potential of saline water. Regarding the addition method, the continuous addition method led to an increase in soil sorptivity compared to the intermittent addition method, regardless of the water salinity level and soil gypsum content. The increased sorptivity values under conditions of continuous water addition may be due to the continued hydraulic pressure and continuous water movement. According to the results of this study, it is necessary to consider the water salinity level and water addition method when managing gypsum soils

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