# EFFECT OF SAND COVERING THICKNESS ON DIFFERENT TILLAGE STATE SOIL WATER AND SALT TRANSPORT LAW UNDER BRACKISH WATER IRRIGATION

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**Abstract.** Using indoor soil column simulation test, this paper contrastively studied the effects of different sand covering thicknesses on decades' tillage land soil and idle land soil water and salt distribution and transport law in the same area under brackish water irrigation. In the test, 4 g/L brackish water was used for irrigation, and the sand covering thickness was selected as 3 cm, 6 cm and 9 cm respectively. With pure soil as a reference, the wetting front, cumulative infiltration, water content and electrical conductivity under each treatment condition were recorded and analyzed. The results showed that for two kinds of soil, 3 cm sand covering can not only promote soil water infiltration, but also effectively alleviate the salinization problem caused by the accumulation of salt surface, with good salt leaching effect; For idle land soil, 6 cm sand covering is good in water retention and salt suppression, and different sand covering thickness all have more positive significance to prevent soil salinization caused by brackish water irrigation than for decades' tillage land soil. Therefore, a reasonable sand cover thickness can be selected according to the soil conditions and farming needs to improve the soil planting environment and optimize the use of water resources.
**Keywords:** *soil, sand covering, cumulative infiltration, brackish water, water and salt transport, water content, electrical conductivity*

## Introduction

The arid and semi-arid areas in Northwest China belong to temperate continental climate, with less annual precipitation, high evaporation intensity, and serious shortage of water resources, which seriously restricts the development of agriculture in this area. In order to alleviate the shortage of agricultural fresh water resources, the development and utilization of brackish water irrigation has become one of the efficient measures widely adopted in arid areas (Wang and Tan, 2016). A large number of research and practice have proved that the rational development and utilization of brackish water is of great significance for alleviating the shortage of agricultural water in arid areas, increasing crop quality and yield and farmers' income, reducing the pressure mining of deep groundwater (Gu et al., 2019; Ma et al., 2019). The arid and semi-arid areas in Northwest China are relatively rich in brackish water resources, which can alleviate the shortage of agricultural water to a certain extent (Li et al., 2022, 2014; Zhou et al., 2013).

However, some scholars found that under the condition of strong evaporation but small rainfall, long-term use of brackish water irrigation will lead to the surface


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accumulation of salt in the soil, and eventually lead to the problem of soil salinization (Liu and Fu, 2004; Zhang and Shen, 2022). Therefore, when using brackish water for irrigation, it is very important for crop growth to reasonably develop and improve soil water and salt environment, and so, in order to avoid salt accumulation and salinization in soil during brackish water irrigation as much as possible, many scholars have conducted a lot of research on the law of water and salt transport, different irrigation methods and covering methods et. under different brackish water salinity (Wang et al., 2019; Wei et al., 2022). It is found that soil surface covering can not only significantly reduce evaporation, but also effectively reduce the upward transport and surface accumulation of salt in the soil (Tan et al., 2018; Sun et al., 2012; Zhou et al., 2013). Soil surface sand covering is one of the oldest soil surface covering methods and an ancient farming method adopted by working people in arid areas to deal with dry drought. It has a history of decades in arid and semi-arid areas of Northwest China, and its application area is also very wide. A large number of research results on the law of soil water and salt transport based on sand covering show that sand covering on the soil surface can effectively inhibit soil water evaporation, improve the soil environment, increase rainwater infiltration, store water and preserve soil moisture, and inhibit salt accumulation (Ma and Tian, 2012; Tan et al., 2017, 2019).

It can be seen that most of the researchers selected coarse sand covering with particle size greater than 2 mm when carrying out this aspect research, while the impact of fine sand covering with particle size less than 2 mm on soil water and salt transport law has hardly been studied. However, the gap between particles in fine sand with particle size less than 2 mm is smaller than that in coarse sand with particle size greater than 2 mm, so the influence of this fine sand covering on soil water and salt transport is certainly different from that of coarse sand covering with particle size greater than 2 mm. Therefore, it is necessary to carry out this research. In addition, there are few studies on the effect of sand thickness on soil water and salt transport in different tillage years.

In view of this, through the indoor soil column infiltration test, this paper intends to compare and analyze the corresponding water and salt transport law of decades' tillage land soil and idle land soil (zero tillage) with different fine sand covering lay and in the arid and semi-arid area of Northwest China under the condition of brackish water irrigation, hoping that the research results can provide some theoretical guidance for the rational use of sand covering in different types of farmland in arid and semi-arid areas to improve the utilization rate of brackish water irrigation.

## Materials and methods

### *Test soils*

Two test soils were taken from decades' tillage land and zero tillage idle land in Hongchengsi Village, Xihe Town, Yongjing County, Gansu Province, China. The conductivity of cultivated soil was 0.336 ms/cm (EC1:5) and that of idle land was 0.714 ms/cm (EC1:5). The particle size of soil and sand materials was analyzed by pipette method. According to the classification standard of soil particle size by international soil society, the soil texture of tillage land is sandy clay loam, and that of idle land is sandy loam. The particle gradation is shown in *Table 1*.

The test brackish water was prepared according to the 4 g/L standard of phreatic water salinity in the loess hilly area of the soil collection area, in which the mass ratio of


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calcium chloride, sodium chloride and magnesium sulfate is 2:1:1, and the proportioning water is pure water (as *Table 2* shows). Its conductivity was 4.29 ms/cm and the sodium adsorption ratio (SAR) is 3.335. The sand used in the experiment was collected from the beach of the river near Hongchengsi village.

***Table 1.*** *Composition of test soil and sand particle size*

| **Particle size (mm)** | **2 ≥ D > 0.2** | **0.2 ≥ D > 0.02** | **0.02 ≥ D > 0.002** | **D > 0.002** |
|---|---|---|---|---|
| Tillage land (%) | **1.2** | 53.8 | 24.5 | 20.5 |
| Idle land (%) | 1.7 | 67.3 | 23.5 | 7.5 |
| Sand (%) | 58.5 | 33.5 | 3.2 | 5.0 |

***Table 2.*** *Proportion of components in brackish water*

| **Chemical composition** | **$MgSO_4$** | **$CaCl_2$** | **NaCl** |
|---|---|---|---|
| Mass ratio | 0.25 | 0.5 | 0.25 |
| Relative molecular mass (g/mol) | 120.37 | 111 | 58.44 |
| Molar ratio | 0.2077 | 0.4505 | 0.4278 |

### *Test method*

In this paper, the indoor soil column infiltration test is adopted, its structure is shown in *Figure 1*.

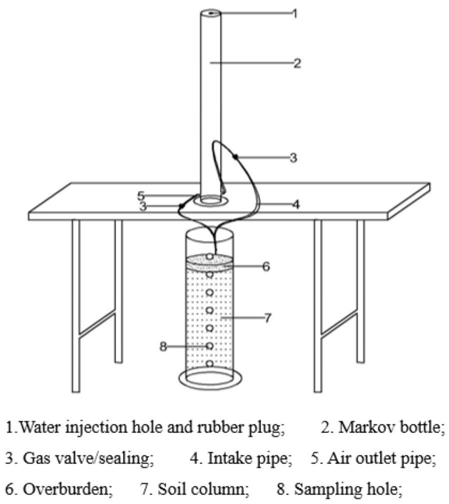


***Figure 1.*** *Schematic diagram of soil column test structure*

Before the test, the soil sample was air dried, impurities were removed, rolled and crushed, and passed through the soil screen with 2 mm aperture. The soil column was made of plexiglass and its specifications were: outer diameter 20 cm, inner diameter 19 cm and height 70 cm. Sampling holes with a diameter of 3 cm were set at 19.5 cm, 27.5 cm, 35.5 cm, 43.5 cm, 51.5 cm and 59.5 cm of the soil column from top to bottom.


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The soil bulk density was controlled to be 1.35 g/cm$^3$, and the soil was loaded with the same quality and thickness. The total loading thickness of soil was 50 cm, and every 5 cm was a layer. Each layer was loaded with 1912.84 g soil, compacted and roughened. When filling the sand covering layer, fill the pure sand to the set thickness according to the unit weight of 1.4 g/cm$^3$, and lightly compact it.

The test was divided into eight groups. 1# soil test was divided into four groups as follows: pure soil 1 (CK1#), 3 cm sand covering (3S1#), 6 cm sand covering (6S1#), 9 cm sand covering (9S1#), 2# soil test was divided into four groups as follows: pure soil 2 (CK2#), 3cm sand covering (3S2#), 6 cm sand covering (6S2#), and 9 cm sand covering (9S2#). During the test, use Markov bottles to supply water continuously and maintain a constant head of 3 cm. When the wetting front reaches 60 cm of the soil column, quickly turn off the water supply valve and drain the accumulated water on the upper layer, and then take soil samples at the sampling hole.

For ease of description, the decades' tillage land soil is marked as 1# soil and the idle land soil is marked as 2# soil.

### *Determination items and methods*

After the start of the test, recorded the position of the wetting front and the water surface scale of the Markov bottle at the time points of 1, 3, 5, 10, 20, 30, 60, 90 and 120 min, and recorded it every 60 min after 120 min. At the end of the test, the soil water content at each sampling point be measured by drying method. Each soil sample was prepared with soil water ratio of 1:5, and the conductivity of the extracted solution was measured by DDS-11A conductivity meter (EC1:5, ms/cm). Took samples again 24 h after the test end to measure the soil water content and electrical conductivity.

Repeat three tests for each group test. When the error of the three groups of measurement data is less than 5%, the average value is taken as the final data. If the data error does not meet the requirements, repeat this test again. All test data were statistically analyzed with Excel2016, and the analysis chart was drawn with Origin11.

### *Calculation method of actual infiltration amount of soil*

Based on the actual situation, a certain amount of water will be held in the sand layer on the soil surface during irrigation after sand covering. Therefore, when calculating the actual infiltration of soil, the amount of water held in the sand covering layer needs to be deducted. At the beginning of the test, due to the existence of the sand layer, the water quickly fills the pores between the sand and gradually reaches saturation. The water storage capacity of sand layers with different thickness is different. When comparing the actual irrigation amount infiltrated into the soil under different sand layer thickness, the following equation is used to calculate the actual infiltration amount in the soil (Song et al., 2012):

$$NI = GI - DS_{Sa} \quad \text{(Eq.1)}$$

In the equation: *NI* is the amount of water infiltrated into homogeneous soil (cm); *GI* is the total infiltration into the total soil containing sand covering (cm); *D* is the thickness of sand covering (cm); $S_{Sa}$ is the saturated water content of sand layer (cm$^3$·cm$^{-3}$).


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## Result analysis

### *Soil vertical wetting front transport law of two soils under different sand covering thickness*

*Figures 2* and *3* show the vertical advance of wetting front when 1#, 2# soil was irrigated with brackish water with salinity of 4 g/L under the conditions of no sand covering, 3 cm sand covering, 6 cm sand covering and 9 cm sand covering respectively.

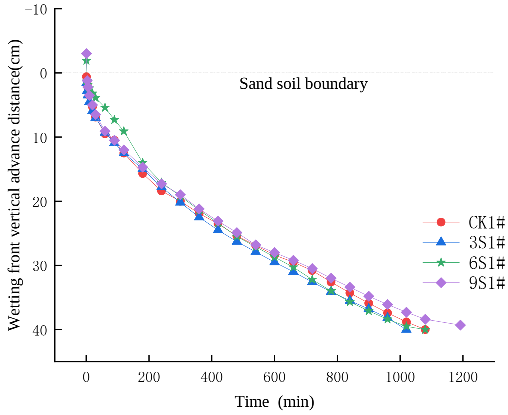


***Figure 2.*** *1# (decades' tillage land) soil wetting front variation trend with infiltration time*

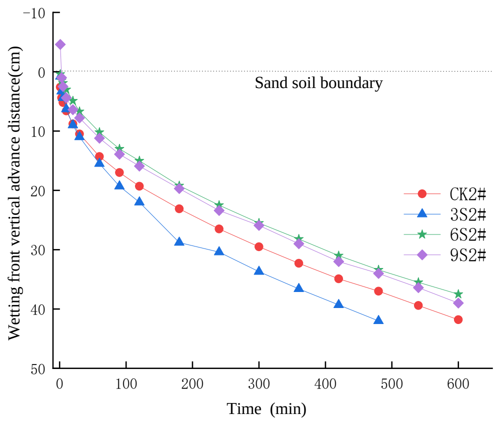


***Figure 3.*** *2# (zero tillage land) soil wetting front variation trend with infiltration time*

It can be seen from *Figure 2*: Due to sand covering, the wetting front depth of 6S1#, 9S1# two test groups at the initial stage of infiltration (within 1 min from the beginning of infiltration) is -1.9 cm and -3 cm respectively, this is because the wetting front has not yet transported from the sand layer to the soil layer at this time. In the range of 20 min to 200 min, the transport depth of 6S1# was significantly smaller than that of the other three groups. The difference of CK1#, 3S1#, 9S1# three test groups in the range of 150 min was not obvious, and after 200 min, the difference of each group tended to be stable. From the beginning of infiltration, the order of wetting front transport depth of each group at same time is 3S1# > CK1# > 6S1# > 9S1#. Until the infiltration time reaches about 450 min, the wetting front of 6S1# gradually exceeds


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CK1#, and then until the end of infiltration, the order of wetting front transport depth continues to be 3S1# > 6S1# > CK1# > 9S1#. It can also be seen from *Figure 2* that the 3 cm sand covering and 6 cm sand covering can promote the transport of wetting front, while 9 cm sand covering can inhibit the transport of wetting front. This is because: the fine sand covering contains a certain amount of very small particles, which will gather at the bottom of the sand covering layer and finally settle on the soil surface with the infiltration of water. When the thickness of the sand covering is small, the content of such particles in the sand layer is small, so it will not affect the effective pores of water through the surface soil. However, with the increase of the thickness of the sand covering, the total amount of such particles in the sand covering will increase, When the thickness of sand covering reaches a certain value, the very small particle layer deposited on the soil surface will start to block the water infiltration, which will become more and more obvious with the further increase of the thickness of sand covering, the effective porosity of water through the surface soil will also be reduced.

It can be seen from *Figure 3*: The difference of wetting front transport depth of CK2#, 3S2#, 9S2#, 6S2# groups at the initial stage of infiltration (within 20 min) is small. After 20 min, the difference of wetting front transport depth of the four test groups becomes more and more obvious, and after 200 min, the difference tends to be stable. From the beginning of infiltration, the transport depth of wetting front in each test group always shows 3S2# > CK2# > 9S2# > 6S2#, and the vertical transport of wetting front is relatively stable. It can also be seen from *Figure 3* that 3 cm sand covering can obviously promote the transport of 2# soil wetting front, while 6 cm sand covering and 9 cm sand covering show inhibition. The inhibition effect of 6 cm sand covering is greater than that of 9 cm sand covering. The reason is that the proportion of clay particles and silt particles in 2 # soil is small. With the increase of sand layer thickness, the retarding effect of fine particles in sand layer on water infiltration is reflected earlier. When the fine particles mixed into the soil surface reached saturation, the retardation began to weaken.

Because 2# soil belongs to the soil that has not been cultivated, its particle structure is quite different from the soil in cultivated land, and it is pure and less impurities. Through comparing *Figures 2* and *3*, it can be seen that the time taken for the wetting front of 1#, 2# two soils to reach the same position is quite different, and the time taken for the wetting front of 2# soil to reach the 60 cm depth of the soil column is about 480 min less than that of 1# soil. The effects of three kinds of sand covering thickness on the transport of wetting front of the two soils are also different. The 3 cm sand covering thickness promotes the transport of 1# and 2# two soils wetting front, but it promotes the transport of 2# soil wetting front more obviously; The 6 cm sand covering thickness promoted the transport of 1# soil wetting front and inhibited the transport of 2# soil wetting front; The 9 cm sand covering thickness inhibited the transport of 1# and 2# soil wetting front, but it inhibited the transport of 2# soil wetting front more obviously.

The power function is used to fit the wetting front and time of the two soils under various test conditions. The fitting results are shown in *Table 3*. In *Table 3*: $\boldsymbol{Zf}$ is the transport distance of wetting front (cm); $\boldsymbol{t}$ is infiltration time (min); $\boldsymbol{m}$, $\boldsymbol{n}$ is the fitting coefficient. It can be seen from *Table 3* that the coefficient $\boldsymbol{R^2}$ of each fitting is greater than 0.98, indicating that the fitting is in good condition, and the transport distance of wetting front has a good power function relationship with time.


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***Table 3.*** *Zf-t fitting of two soils under different treatments*

| Sand covering thickness (cm) | | 0 | 3 | 6 | 9 |
|---|---|---|---|---|---|
| 1# | ***m*** | 1.1657 | 1.1635 | 0.4523 | 0.9790 |
| | ***n*** | 0.4988 | 0.5043 | 0.6505 | 0.5236 |
| | $R^2$ | 0.9990 | 0.9972 | 0.9939 | 0.9918 |
| | $Zf = mt^n$ | $Zf = 1.1657t^{0.4988}$ | $Zf = 1.1635t^{0.5043}$ | $Zf = 0.4523t^{0.6505}$ | $Zf = 0.9790t^{0.5236}$ |
| 2# | ***m*** | 2.1804 | 2.2070 | 0.9417 | 1.0793 |
| | ***n*** | 0.4589 | 0.4786 | 0.5775 | 0.5600 |
| | $R^2$ | 0.9989 | 0.9967 | 0.9993 | 0.9874 |
| | $Zf = mt^n$ | $Zf = 2.1804t^{0.4589}$ | $Zf = 2.2070t^{0.4786}$ | $Zf = 0.9417t^{0.5775}$ | $Zf = 1.0793t^{0.5600}$ |

## *Cumulative infiltration of two soils*

*Figures 4* and *5* respectively show the variation law of cumulative infiltration of 1#, 2# two soils under pure soil test group, 3 cm, 6 cm and 9 cm sand covering thickness conditions, when irrigated with 4 g/L brackish water.

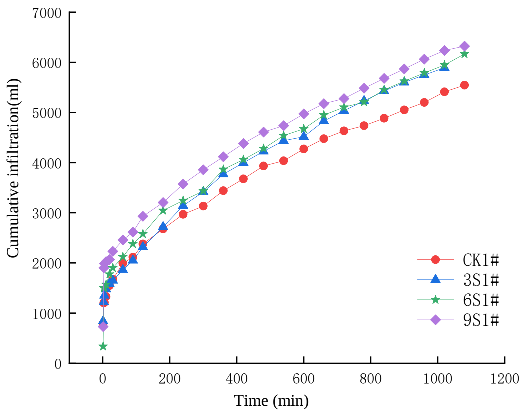


***Figure 4.*** *Variation trend of 1# (decades' tillage land) soil cumulative infiltration with infiltration time*

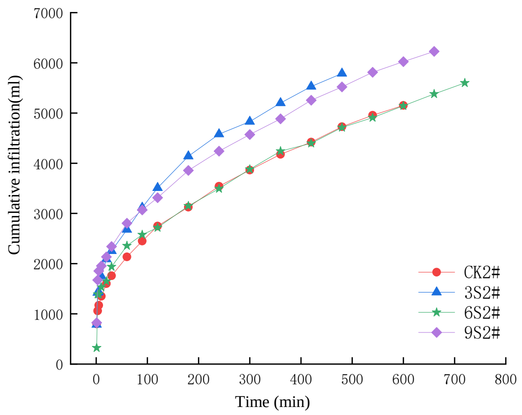


***Figure 5.*** *Variation trend of 2# (zero tillage land) soil cumulative infiltration with infiltration time*


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As shown in *Figure 4*, under the 3 cm sand covering thickness, 1# soil has the largest cumulative infiltration and the largest transport distance of wetting front, indicating that the 3 cm sand covering thickness can significantly promote the infiltration of water in 1# soil. In the process of infiltration, the variation trend of cumulative infiltration under each sand covering thickness is basically the same, and the infiltration rate is similar; The order of cumulative infiltration recorded at each time recording point is:9S1# > 6S1# > 3S1# > CK1#. At the end of infiltration, the cumulative infiltration under 9S1#, 6S1#, 3S1# increased by 20.8%, 10.6% and 6.3% respectively compared with CK1#. This shows that the thicker the sand covering is, the greater the cumulative infiltration of the soil and the corresponding increase of the soil infiltration rate.

The test shows that the saturated water content in 3 cm, 6 cm and 9 cm sand covering is 317.7 g, 629.1 g and 943.6 g respectively. If the water content in the sand covering at the end of infiltration is not included, at the end of the test, the cumulative infiltration of 1# soil CK1#, 3S1#, 6S1#, 9S1# four groups is 5544.7 ml, 5572.3 ml, 5536 ml and 5527 ml respectively, in the order of 3S1# > CK1# > 6S1# > 9S1#.

Due to the different properties of soils, the cumulative infiltration of 2# soil is obviously different from that of 1# soil. As shown in *Figure 5*, at the initial stage of infiltration, the infiltration of 9S2# increased rapidly due to the existence of sand covering, but after 90 min, the cumulative infiltration of 3S2# gradually exceeded that of other test groups, and the infiltration ended first. After 540 min, the cumulative infiltration of 9S2# gradually exceeded CK1#. CK2# and 6S2# are almost on the same curve after 120 min, indicating that the infiltration effect of 6 cm sand covering is little than that of pure soil. However, after the infiltration of CKS2# reached the limited infiltration depth, the cumulative infiltration of 6S2# continues to increase in the following 120 min. In general, from the cumulative infiltration of each test group, the cumulative infiltration of 9S2#, 6S2#, 3S2# test groups were 19.97%, 8.3% and 11.8% higher than cumulative infiltration of CK2# at the end of infiltration. It shows that no matter the thickness of sand covering is 3 cm, 6 cm or 9 cm, it can significantly promote the cumulative infiltration of soil, of which 9S2# effect is the most obvious.

### *Calculation method of actual infiltration amount of soil*

According to the calculation equation (Eq.1) of actual infiltration amount of soil, after deducting the amount of water accumulated in the sand covering layer, the actual cumulative infiltration amount of 2# soil CK2#, 3S2#, 6S2#, 9S2# four test groups at the end of the test is 4727.9 ml, 5470.5 ml, 4083.15 ml and 4577.5 ml respectively, in the order of 3S2# > CK2# > 9S2# > 6S2#. It can be seen that 2# soil under the condition of 3 cm sand covering has faster cumulative infiltration and wetting front transport than its pure soil group, indicating that 3 cm sand covering treatment can effectively increase the infiltration capacity of soil water. This conclusion is similar to that of 1# soil.

Kostiakov model is used to fit the relationship between cumulative infiltration and time of the two soils. The results are shown in *Table 4*. In *Table 4*: $I$ is the cumulative infiltration volume (ml); $t$ is infiltration time (min); $k$ is the infiltration coefficient; $a$ is the infiltration index. It can be seen from *Table 4* that the coefficient $R^2$ of each fitting is greater than 0.98, indicating that the relationship between cumulative infiltration and time described by Kostiakov model is consistent with the test conditions of these two soils.


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***Table 4.*** *The results of cumulative infiltration and time results of two soil test groups simulated by Kostiakov model*

| **Sand covering thickness (cm)** | | **0** | **3** | **6** | **9** |
|---|---|---|---|---|---|
| **1#** | $k$ | 584.94 | 550.46 | 671.61 | 972.88 |
| | $a$ | 0.30762 | 0.32797 | 0.30022 | 0.24925 |
| | $R^2$ | 0.9785 | 0.96514 | 0.96571 | 0.95064 |
| | $I = kt^a$ | $I = 548.94t^{0.30762}$ | $I = 550.46t^{0.32797}$ | $I = 671.61t^{0.30022}$ | $I = 972.88t^{0.24925}$ |
| **2#** | $k$ | 563.06 | 781.31 | 611.39 | 875.61 |
| | $a$ | 0.34123 | 0.32119 | 0.3301 | 0.29612 |
| | $R^2$ | 0.98959 | 0.99301 | 0.98048 | 0.98049 |
| | $I = kt^a$ | $I = 563.06t^{0.34123}$ | $I = 781.31t^{0.32119}$ | $I = 611.39t^{0.3301}$ | $I = 875.61t^{0.29612}$ |

### *The water content when the irrigation was stopped and its redistribution 24 h after the stopping irrigation*

*Figures 6* and *7* show the water content of each test group of 1# soil when irrigation was stopped and the redistribution after 24 h stopping irrigation. It can be seen from *Figure 6* that when irrigation was stopped, the order of water content of each test group at the first sampling hole is CK1# > 3S1# > 6S1# > 9S1#. The average water content of each test group is CK1#: 29.4%; 3S1#: 28.9%; 6S1#: 26.83%; 9S1#: 28.31%. It can be seen from *Figure 7*, except for sampling hole 1, the water content difference of other sampling holes is small, and the distribution is relatively uniform 24 h after stopping irrigation. The average water content is CK1#: 26.4%; 3S1#: 5.83%; 6S1#: 26.15%; 9S1#: 27.6% respectively. The water retention performance is 9S1# > CK1# > 6S1# > 3S1#, which is mainly because the water retention performance of the soil is affected by the upper sand covering, and the pores in the sand covering are large, which increases the amount of irrigation. At the same time, the existence of sand covering cuts off the direct contact between soil and atmosphere and slows down the evaporation of soil surface. It can be seen from *Figure 7* that no matter what kind of sand covering, the water content at about 8 cm under the soil layer is the highest 24 h after stopping irrigation. This depth is just the water absorption depth of plant roots, which is of positive significance to plant water absorption.

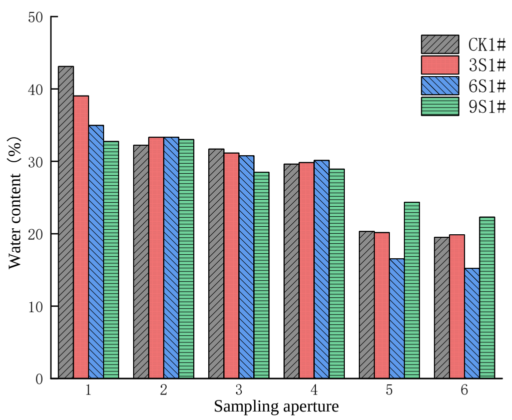


***Figure 6.*** *1# (decades' tillage land) soil water content of each sampling hole when the soil irrigation was stopped*


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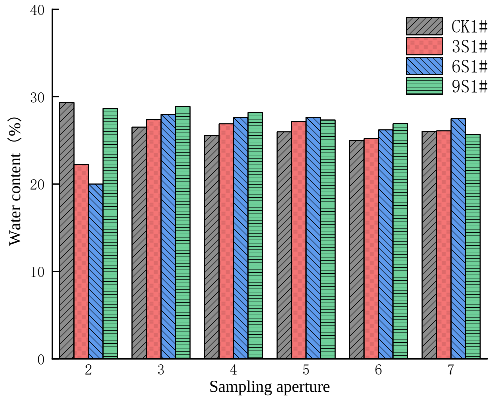


***Figure 7.*** *1# (decades' tillage land) soil water content of each sampling hole 24 h after stopping irrigation*

The particle composition of 2# soil and 1# soil is different, so the variation law of soil water content is also different. *Figures 8* and *9* show the water content of each test group of 2# soil when the irrigation was stopped and the redistribution 24 h after stopping irrigation. It can be seen from *Figure 8*, the average soil water content of each test group when stopping irrigation is: CK2#: 26.28%, 3S2#: 28.53%, 6S2#: 27.15%, 9S2#: 27.13%. The average water content of 3S2# is the largest, and the water content of sampling its holes 1, 2 and 3 is greater than that of other groups, but the water content of sampling holes 5 and 6 are the lowest. In addition, just as show Section above that the 3S2# infiltration rate is the largest, indicating that 3 cm sand covering can not only improve the infiltration rate, at the same time, it can also make the upper soil (0-24 cm) have better water retention. The order of the average value of water content redistributed 24 h after stopping irrigation is 9S2# > 6S2# > CK2# > 3S2#, which is similar to 1# soil.

### *The soil electrical conductivity when the irrigation was stopped and its redistribution 24 h after stopping irrigation*

There is a positive correlation between soil salt content and electrical conductivity, so in this paper, the electrical conductivity is used to describe the salt content in soil. *Figures 10* and *11* show the conductivity of each 1# soil test group when the irrigation was stopped and its redistribution 24 h after stopping irrigation.

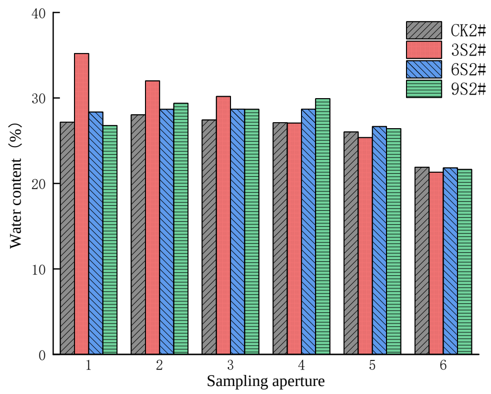


***Figure 8.*** *2# (zero tillage land) soil water content of each sampling hole when the soil irrigation was stopped*


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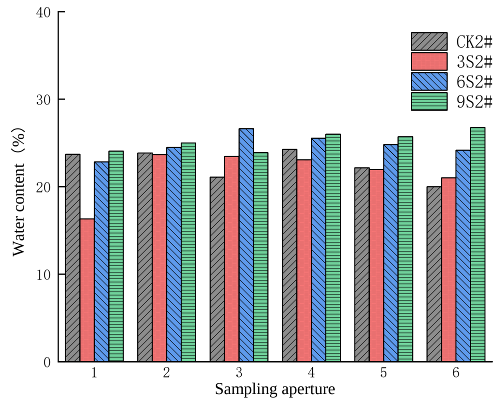


***Figure 9.*** *2# (zero tillage land) soil water content of each sampling hole 24 h after stopping irrigation*

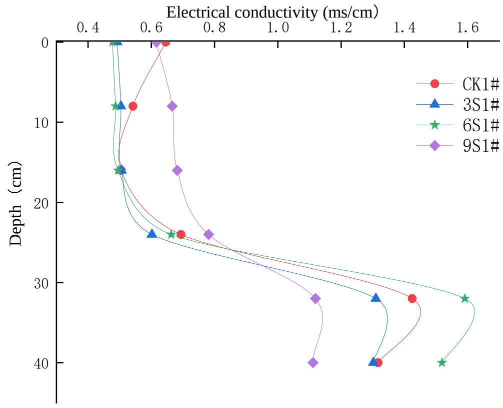


***Figure 10.*** *1# (decades' tillage land) soil electrical conductivity of each sampling hole when the soil irrigation was stopped*

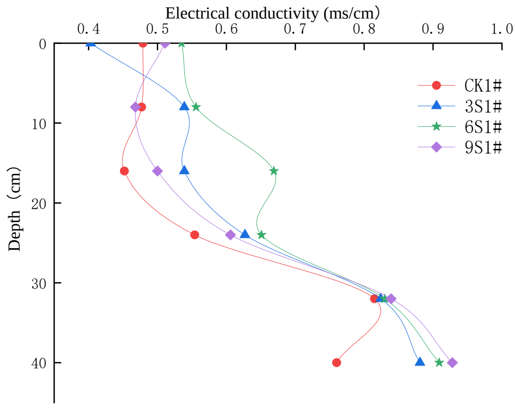


***Figure 11.*** *1# (decades' tillage land) soil electrical conductivity of each sampling hole 24 h after stopping irrigation*

*Figure 10* shows the variation of electrical conductivity with depth for each 1# soil test group, it can be seen from *Figure 10* that the soil surface electrical conductivity of


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CK1#, 3S1#, 6S1#, 9S1# test groups is 0.646 ms/cm, 0.492 ms/cm, 0.477 ms/cm and 0.616 ms/cm respectively. Because the sand covering can absorb some salt ions and dilute the brackish water infiltrated into the soil (Song et al., 2012), so the soil surface electrical conductivity of the sand covering test group is lower than that of the pure soil group, and 6 cm sand covering (6S1#) has the best effect on the reduction of soil surface salt. The electrical conductivity of 3S1#, 6S1#, 9S1# three test groups increases slowly in the depth range of 20-45 cm, while CK1# decreases in this range, showing a "***C***" distribution. The electrical conductivity of each sand covering test group increased sharply in the depth range of 45-55 cm, showing an "***L***" distribution. The maximum electrical conductivity of each test group appears near the wetting front, in the order of 6S1# > CK1# > 3S1# > 9S1#, it shows the 6 cm sand covering (6S1#) can fully transfer the salt in the upper soil to the lower soil, and the salt leaching effect is the most obvious.

It can be seen from *Figure 11* that the soil surface electrical conductivity of 3S1# test group is the lowest 24 h after stopping irrigation, it is because 3 cm sand covering can inhibit the water salt separation and salt surface accumulation caused by the upward evaporation of salt with capillary water under the action of evaporation. Therefore, when irrigated with brackish water, 3 cm sand covering can effectively alleviate the salinization caused by salt surface accumulation, and has a good salt leaching effect, which is of positive significance to plant growth. After 24 h of water and salt redistribution, the conductivity of CK1#, 9S1# two test groups are lower than that of stopping irrigation, and the electrical conductivity of 6S1# test group increases significantly from soil surface to 24 cm depth, which is higher than that of the other three test groups. To sum up, although the 6S1# test group has the best effect of salt transport downward during the test, after 24 h of water and salt redistribution, a large amount of salt migrated to the depth of 15-24 cm soil and gathered significantly here.

*Figures 12* and *13* show the electrical conductivity of each 2# soil test group when the irrigation is stopped and its redistribution 24 h after stopping irrigation.

As shown in *Figures 12* and *13* that the distribution of soil salt content in each 2# soil test group is very different from each 1# soil test group when irrigation was stopped. It can be seen from *Figure 12*, the electrical conductivity of all 2# soil test groups increased sharply at 0-8 cm depth, of which 9S2# test group increased the most, with a value of 0.368 ms/cm. In addition, according to the curve shape, the electrical conductivity of all 2# soil gradually increases with depth, and the salt in the soil moves downward with water, reaching the maximum at the wetting front.

After 24 h water and salt redistribution, the electrical conductivity of the soil surface of each 2# soil test group is very different from that when the irrigation was stopped, and their order is as follows: CK2# > 3S2# > 9S2# > 6S2#, and the electrical conductivity of CK2#, 3S2# increases by 0.069 ms/cm and 0.162 ms/cm respectively compared with that at the time of stopping irrigation, which indicates that the phenomenon of "salt goes with the water, water goes but salt remains" appears on the soil surface of CK2#, 3S2# two test groups. The conductivity of 6S2#, 9S2# two test groups decreased by 0.089 ms/cm and 0.14 ms/cm respectively compared with that at the time of stopping irrigation, and the electrical conductivity of 6S2# soil surface was the smallest, indicating that 6S2# can effectively prevent the upward transport and evaporation of soil salt under the action of capillary water and the accumulation of soil surface salt after irrigation.


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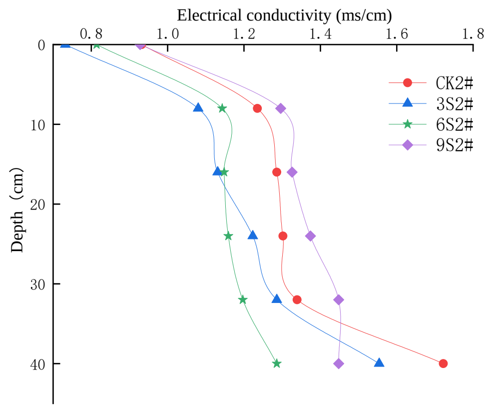


***Figure 12.*** *2# (zero tillage land) soil electrical conductivity of each sampling hole when the soil irrigation was stopped*

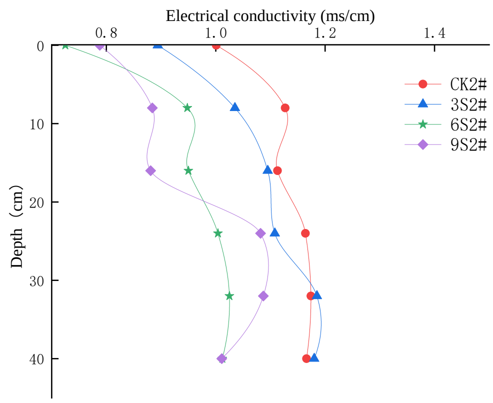


***Figure 13.*** *2# (zero tillage land) soil electrical conductivity of each sampling hole 24 h after stopping irrigation*

## Conclusion

In this paper, the effects of different sand covering thickness under brackish water irrigation on the distribution and transport of water and salt in decades’ tillage land soil (1# soil) and zero tillage idle land soil (2# soil) in the same area are studied by indoor soil column simulation test. The conclusions are as follows:

(1) For the decades’ tillage land soil (1# soil), when 4 g/L brackish water is used for irrigation, the cumulative infiltration of 3 cm sand covering (3S1#) test group is the largest distance from the transport of wetting front, which shows 3 cm sand covering which can significantly promote the infiltration of water into the soil; 9 cm sand covering can inhibit the transport of wetting front, but can increase the amount of irrigation, and its water retention performance is the best after 24 h water redistribution; 3 cm, 6 cm and 9 cm sand covering can improve the soil water content after irrigation, absorb some salt ions and dilute brackish water. When irrigation was stopped, the salt content in the pure soil test group is “***C***” distribution, and the salt content in the sand covering test group is “***L***” distribution; The salt leaching effect of 6 cm sand covering is the most obvious, which can reduce the soil surface salt brought by brackish water


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irrigation, but after 24 h redistribution, the salt accumulates at the depth of 15-24 cm; It can be seen from the redistribution of salt 24 h after stopping irrigation that 3 cm sand covering can more effectively alleviate the salinization problem caused by soil surface accumulation and has a good salt leaching effect.

(2) For the zero-tillage land soil (2# soil): 3 cm sand covering can increase the infiltration rate and make the upper soil (0-24 cm) have better water retention; Compared with the pure soil test group, the cumulative irrigation amount of 9 cm sand covering (9S2#) test group increased by 19.97%, and the average value of redistribution moisture content after 24 h was the largest, indicating that the water retention performance of 9 cm sand covering was the best after 24 h redistribution. The sand covering thickness of 3 cm, 6 cm and 9 cm has a positive effect on preventing soil salinization caused by brackish water irrigation, 6 cm sand covering thickness can significantly prevent soil surface salinization, and it has a good comprehensive performance in water conservation and salt suppression.

## Discussion

It can be seen from above conclusion that, for two kinds of soil, the 3 cm thick sand covering can not only promote the infiltration of soil water, but also effectively alleviate the salinization problem caused by the accumulation of salt surface, with good salt leaching effect, which is similar to the results of existing studies. Because the fine sand with the particle size less than 2 mm is selected in this paper, its role in promoting water infiltration is weaker than that of coarse sand, However, its effect on preventing soil salinization caused by brackish water irrigation is stronger than that of coarse sand; 6 cm sand covering also has a stronger effect than coarse sand in preventing soil salinization caused by brackish water irrigation, and 6 cm sand covering also promotes the water infiltration of sandy clay (1 #), but it inhibits the water infiltration of sandy soil (2 #), while 9 cm sand covering also inhibits the water infiltration of soil, which is different from coarse sand. Therefore, when selecting fine sand with particle size less than 2 mm as the sand covering layer, it is recommended to select a thickness of 3 cm.

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