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Effects of Irrigation Regimes on Soil Water Dynamics of Two Typical Woody Halophyte Species in Taklimakan Desert Highway Shelterbelt

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Abstract: Freshwater resources are in a shortage in arid regions worldwide, especially in extremely arid desert areas. To solve this problem, highly saline groundwater is used for drip irrigation of desert plants. Since more irrigation infiltrating into the deep soil cannot be absorbed and utilized by desert plants, it is crucial to determine optimal water-saving irrigation regimes. In this study, we examined the effects of irrigation regimes on the soil water dynamics of two typical woody halophyte species (*Haloxylon* and *Calligonum*), and quantified the irrigation intervals and periods based on a field test of precision irrigation control in the Taklimakan Desert Highway shelterbelt. Results showed that the change in soil moisture of two species in the shallow 0–60 cm layer could be divided into a rapid decline period (1–9 d), a slow decline period (9–19 d), and a relatively stable period (19–39 d) after irrigation. The decrease rate of soil moisture at the 0–60 cm depth was significantly higher than that at the 60–200 cm depth. The irrigation regime combining 35 mm irrigation with 10 days was beneficial to soil water storage and plant use with respect to *Calligonum*, while the irrigation regime combining 35 mm irrigation with 40 days was best for *Haloxylon*. Increasing the single irrigation amount and prolonging the irrigation period can further enable the more effective use of irrigation water. This study highlights that saline groundwater irrigation provides potential advantages for desert plants' survival under reasonable irrigation regimes.

Keywords: irrigation amount; irrigation periods; Taklimakan Desert Highway shelterbelt; soil water storage; woody halophyte; saline-tolerant plant

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1. Introduction

Desertification is an environmental issue of global concern, especially in arid and semiarid regions. Artificial afforestation has been considered an effective ecological means for combating desertification in many arid desert regions worldwide [1,2]. Great challenges, however, have appeared when the afforestation is conducted in arid desert regions due to the lack of freshwater and extreme environmental conditions, including severe drought [1,3,4]. Due to less rainfall in arid desert regions, water scarcity has become a worldwide issue of increasing severity [1,5]. The lower-quality saline–alkaline groundwater is widely applied [6–8]. Unfortunately, saline water irrigation normally leads to greater salinity hazards to plant growth and survival in groundwater extraction [9,10]. Therefore, establishing a suitable irrigation regime for artificial vegetation growth and survival is crucial to saving groundwater utilization and reducing the salinity hazards.

The Taklimakan Desert, called the "Dead Sea", is the second-largest mobile desert in the world. To improve transportation for the exploitation of petroleum resources, the Taklimakan Desert Highway, the longest highway across a shifting desert in the world, was completed in 1995 [11]. To overcome the frequent sand burial of the highway, the Taklimakan Desert Highway shelterbelt was constructed through a biological engineering project in 2003 [12]. The mobile dunes on both sides of the highway were effectively stabilized by introducing drought- and salt-tolerant plants [13], such as *Haloxylon Bunge*, *Calligonum Linn*, and *Tamarix Linn.*

Drip irrigation from saline groundwater is one of the most efficient ways to support artificial shelterbelts [14]. Owing to the differences in the adaptability or adaptive strategies of drought- and salt-tolerant plants, irregular or insufficient irrigation will lead to different responses of plants to water stresses [14]. Therefore, it is crucial to determine suitable irrigation regimes to ensure plant survival in the drip irrigation process. *Haloxylon ammodendron* and *Calligonum mongolicunl* are the two main species in the Taklimakan Desert Highway shelterbelt. It is reported that moderate irrigation intervals are beneficial to the growth of the two species in the Taklimakan Desert Highway shelterbelt since they can save water and support the plants' water demands [14].

In recent years, many researchers have studied the soil water dynamics and irrigation regimes of desert plants. For example, Ding et al. reported that the soil moisture at 0–120 cm depth presents an apparent single-peak curve. The salt accumulation phenomenon is evident at 45–60 cm, and the salt content reaches 10–20 g kg^{-1} in the Taklimakan Desert [15]. Li et al. found that saltwater irrigation did not produce salt stress on the plant roots in the Taklimakan Desert [1]. *Haloxylon ammodendron*'s roots are mainly distributed between 20 and 80 cm, while the salt is mainly concentrated in the 0–20 cm surface layer. On the contrary, saline water irrigation is beneficial for increasing soil nutrients. Fu et al. pointed out that *Haloxylon ammodendron* mainly utilizes shallow soil moisture (20–40 cm) and deep soil moisture (100–350 cm) and underground water in May, but deep soil moisture (160–350 cm) and underground water in August in the southern edge of Gurbantunggut Desert [16]. Zhang et al. indicated that the structural heterogeneity of the soil layer has a retarding effect on water content [17]. The soil layers with more clay and silt particles are more prone to salt accumulation at the southern edge of the Gurbantunggut Desert [17].

The previous studies focused mainly on saline water irrigation and its influence on soil properties and plant growth [6,18,19]. However, the effects of saline water irrigation regimes on the soil water dynamics of desert plants have been ignored. Meanwhile, the number of irrigation intervals and periods of different desert plants remain unknown. This study aims to (1) examine the effects of irrigation regimes on the soil water dynamics of two typical woody halophyte species and (2) quantify the irrigation intervals and periods of the two species based on a field test of precision irrigation control. This will provide the theoretical basis for developing water-saving irrigation measures in the shelterbelt.

2. Materials and Methods

2.1. Study Area

This study was carried out in the Taklimakan Desert Highway shelterbelt, which was built from Xiaotang to Minfeng, being 436 km long and 72–78 m wide (Figure 1a). It is characterized by an extremely high temperature, less rainfall, and strong evaporation. According to the Tazhong meteorological station (83°48′14.169″ E,38°54′2.038″ N), the average annual temperature in this area is 12.4 °C. The extreme minimum temperature is −22.2 °C, and the extreme maximum temperature reaches 45.6 °C. The average annual rainfall is 24.6 mm, while the average annual evaporation is 3639 mm. The average relative humidity is only 29.4% (Figure 1b). The average annual wind speed is 2.5 m s^{-1}, and the maximum instantaneous wind speed reaches 20 m s^{-1} [15]. The soil type is mobile aeolian soil, and the soil salt content is 1.26–1.63 g kg^{-1} [19]. The soil physical properties in this area have been described by Zhang et al. [2].

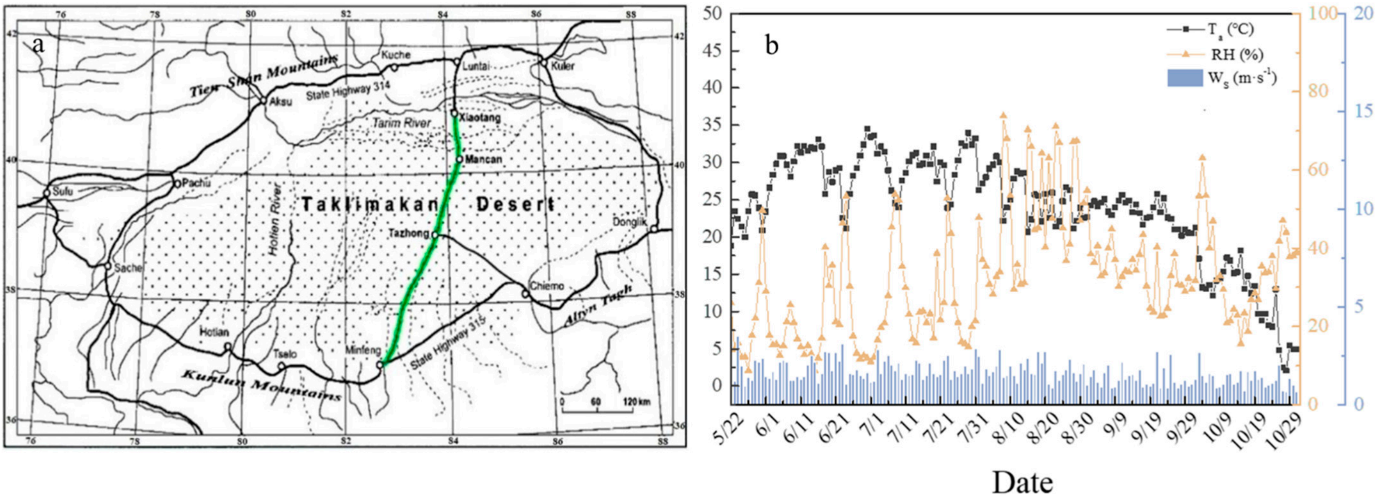

Figure 1. Taklimakan Desert Highway (**a**), and atmospheric temperature (T_a), air humidity (RH), and wind speed (W_S) at the height of 2 m in the middle of the Taklimakan Desert in 2016 (**b**).

The vegetation community is very sparse, and most areas have no vegetation [18]. *Haloxylon ammodendron*, *Calligonum mongolicum*, and *Tamarix L* are the main three species in the Taklimakan Desert Highway shelterbelt (Figure 2). Saline groundwater was used for drip irrigation. The salinity of irrigation water was 4.03 g L^{-1}; the irrigation period was one time every 10 days in July and August, and 15 days in other months, while there was no irrigation in winter (from November to February of the following year). The irrigation amount was 35 mm each time [11].

Figure 2. Three main species in Taklimakan Desert Highway shelterbelt (adapted from Zhang et al. [2]).

2.2. Experiment Design and Data Processing

This experiment selected six rows of well-growing trees in the Taklimakan Desert Highway shelterbelt for irrigation treatment, with each row of approximately 100 m. *Haloxylon ammodendron* and *Calligonum mongolicum* were planted 8 years ago. The same irrigation amount was adopted, and a small switch was installed on the drip irrigation pipe to control the irrigation period. The distance between two rows of plants was at least 5 m. Two rows of trees were planted in each row with a 1 m spacing. Drip irrigation pipes were laid close to the trunk, and the water outlet holes were spaced by 1 m. Three irrigation levels were set, W1 = 17.5 mm, W2 = 25 mm, and W3 = 35 mm, and the three irrigation periods were F1 = 10 d, F2 = 20 d, F3 = 40 d. The samples were taken from different plants in each treatment plot. Three plants were selected from each treatment plot and one sample was taken from each plant for a total of three repetitions. Moreover, in the experiment design, the W1F1, W1F2, W1F3, W3F1, and W3F2 treatments were selected in order to analyze the effects of different combinations of irrigation amount and irrigation period on soil moisture under the same total amount of irrigation over 40 days. The total irrigation amount of the W1F1 and W3F2 treatments in 40 days was 70 mm. The total irrigation amount of the W1F2 and W3F1 treatments was 35 mm in 40 days, and that of the W1F3 treatment was 17.5 mm in 40 days. The combination of irrigation amount and irrigation period for W1 and W3 only allowed the same combination of total irrigation amount. In contrast, the irrigation level of W2 was different from the total irrigation amount of other treatments within 40 days, so the W2 treatment was not selected in this study. The specific field configuration is shown in Figure 3.

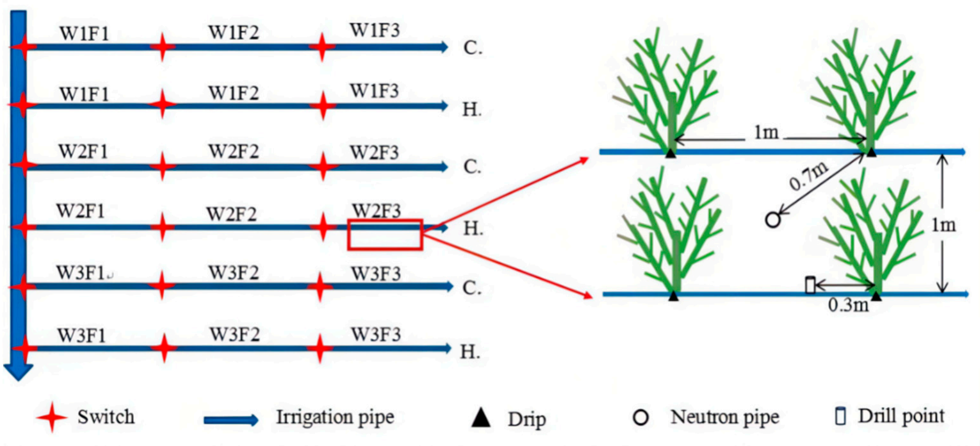

Figure 3. Schematic diagram of field experiment design. (C. means *Calligonum mongolicum*; H. means *Haloxylon ammodendron*; hereinafter the same).

Before the test, three water outlet holes were selected under the drip irrigation pipe in each plot, and a measuring cylinder was placed under each outlet hole to measure the average water output per unit time of each drip irrigation pipe. From 10 August to 20 September 2015, soil samples drilled at 30 cm from the root in each cell were taken at a depth of 0–200 cm (0–10 cm, 10–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, 80–100 cm, 100–120 cm, 120–140 cm, 140–160 cm, 160–180 cm, 180–200 cm) on the 1st, 4th, 9th, 14th, 19th, 29th, and 39th days after irrigation, to evaluate the differences in soil moisture changes under different irrigation strategies with the same irrigation amount of 40 days.

To analyze the change in soil moisture in the whole plot in different months, a 1-m long aluminum tube instrument with LNW-50A neutron probes (CAS, Nanjing, Jiangsu, CHN, 1986) was used for measurement. The neutron tubes were buried in the middle of each plot in 2016. The horizontal distance between the neutron tube and the dropper was 70 cm, and the buried depth was 320 cm. Before the measurement, the neutron instrument was calibrated in layers (0–40 cm and 40–300 cm). It was drilled at a horizontal distance of 30 cm from the dropper to a depth of 200 cm with each 20 cm layer. Each day before irrigation was selected to measure the soil water moisture by drilling and neutron meter in May, July, August, and September of 2016.

After the drilling samples were taken, they were packed into a numbered aluminum box and weighed immediately. Then, the samples were returned to the laboratory and dried in an oven until the constant weight was determined again. The soil mass moisture content was calculated by the calibration curve.

Data statistics and analysis were performed with Excel and SPSS, and plotted with Origin software. Inter-treatment comparisons were compared by one-way ANOVA.

3. Results

3.1. Effect of Irrigation Period on the Spatial Distribution of Soil Water Content

To compare the effects of different irrigation regimes on soil water content, the W1F1, W1F2, W3F1, W3F1, W3F2, and W3F3 treatments in July 2016 (10 d after irrigation) have been selected to analyze the spatial distribution characteristics of soil water content (Table 1).

Table 1. Experimental treatments.

Processing Number	Single Irrigation Volume (mm)	Irrigation Period (d)	Total Irrigation Volume at 40 Days (mm)
W3F1	35	10	140
W3F2	35	20	70
W3F3	35	40	35
W1F1	17.5	10	70
W1F2	17.5	20	35

Under the same irrigation regime, the soil moisture availability shows a clear difference due to the different root growth distributions of *Haloxylon ammodendron* and *Calligonum mongolicum* (Figure 4). In the vertical depth, the soil water content of *Calligonum mongolicum* at 0–100 cm is greater than 100–200 cm in all treatments. The soil water content of *Haloxylon ammodendron* at 0–100 cm in the W3F1 and W3F2 treatments is less than 100–200 cm, and vice versa under other treatments. At the horizontal distance, the soil water content of *Calligonum mongolicum* at 30 cm under the W3F1 and W3F2 treatments is less than 70 cm, and vice versa under other treatments. The soil water content of *Haloxylon ammodendron* at 30 cm under the W3F1, W3F2, and W1F1 treatments is less than 70 cm, and vice versa under other treatments.

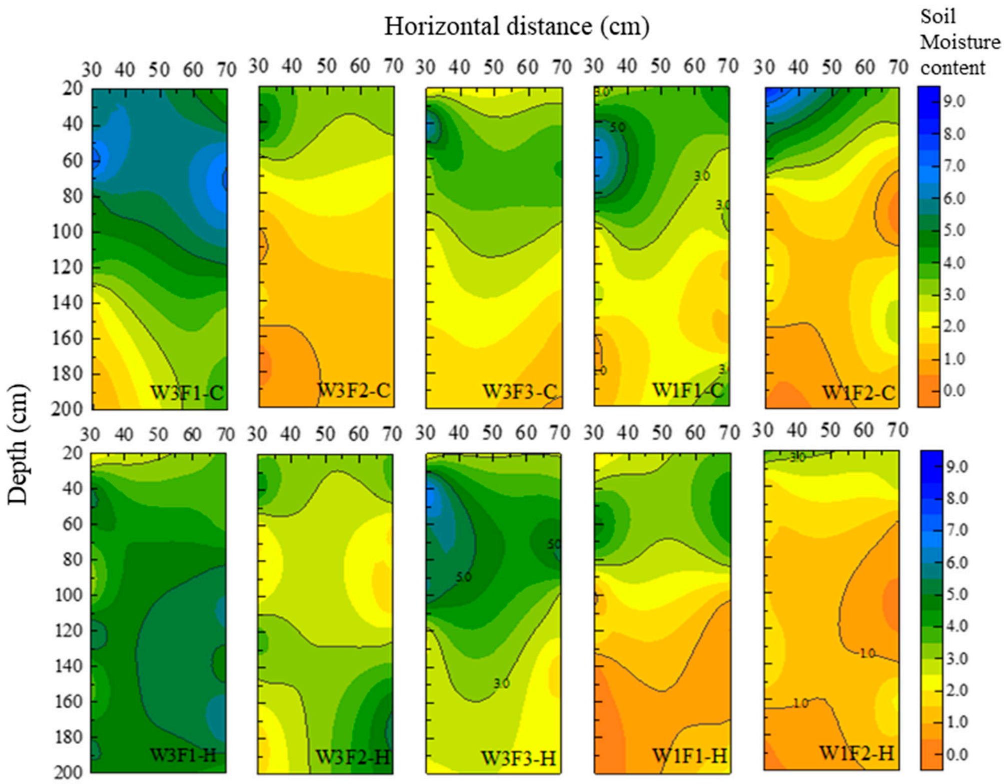

Figure 4. Spatial variation in soil moisture content under different irrigation periods. The soil moisture content in the low (W1), medium (W2), and high (W3) irrigation amounts. F means irrigation frequency with F1 = 10 d, F2 = 20 d, F3 = 40 d. C and H represent *C. mongolicum* and *H. ammodendron*, respectively.

One-way ANOVA is used to compare the differences in soil water content between the treatments shown in Table 2. The soil samples taken at different soil depths obey normal distribution according to the Kolmogorov–Smirnov test. In addition, the F-test of equality of variances with the Least Significance Difference (LSD) test shows the homogeneity of variance. Therefore, one-way ANOVA is suitable for statistical analysis. One-way ANOVA displays the differences in soil water content between treatments at the 0.05 significance level. The mean soil water content of *Calligonum mongolicum* at 0–200 cm is W3F1 > W1F1 > W3F3 > W1F2 > W3F2, while the mean soil water content of *Haloxylon ammodendron* at 0–200 cm is W3F1 > W3F3 > W3F2 > W1F1 > W1F2. Under a 35 mm single irrigation amount, the soil moisture content varies significantly between F1 and F2, F1 and F3, but not significantly between F2 and F3 under a 17.5 mm (strain grade) single irrigation amount; the soil water content is F1 > F2, but this is not significant during the study periods. For the same total water irrigation amount, the difference in soil water content between W3F2 and W1F1, W3F3 and W1F2 are insignificant in the *Calligonum mongolicum*, but both are significant in the *Haloxylon ammodendron*. Under a 70 mm total water irrigation amount, the difference in soil water content of *Haloxylon ammodendron* is mainly focused at the 100–200 cm layer. Under 35 mm water irrigation, the soil moisture of the two species is significantly different between 0–100 cm and 100–200 cm.

Table 2. Soil moisture content between different treatments ($p < 0.05$).

Treatment	Soil Water Content %					
	0–100 cm		100–200 cm		0–200 cm	
	Average Value	Standard Deviation	Average Value	Standard Deviation	Average Value	Standard Deviation
W3F1-C	5.73 a	1.08	2.93 a	1.29	4.33 a	1.84
W3F2-C	2.72 b	1.10	1.15 b	0.46	1.93 b	1.15
W3F3-C	3.37 b	1.26	1.70 b	0.45	2.53 b	1.26
W1F1-C	3.92 b	1.41	1.93 b	1.01	2.93 b	1.58
W1F2-C	2.95 b	2.45	1.57 b	0.81	2.26 b	1.95
W3F1-H	3.97 ab	1.03	4.90 a	0.70	4.44 a	0.99
W3F2-H	2.69 bc	0.91	3.43 b	1.17	3.06 b	1.11
W3F3-H	4.43 a	1.42	2.43 c	0.34	3.43 b	1.44
W1F1-H	3.09 ab	1.32	0.86 d	0.71	1.97 c	1.54
W1F2-H	1.76 c	1.01	1.20 d	0.59	1.48 c	0.87

Note: A lowercase letter indicates a significant difference ($p = 0.05$) after irrigation at the different intervals. The markers (a, b, c) with different letters differ significantly ($p < 0.05$) according to Least Significance Difference test.

3.2. Temporal Variation in Soil Moisture Profile during Irrigation Period under Different Irrigation Regimes

According to the W1F1, W1F2, W3F1, W3F2, and W3F3 treatments, the dynamic changes in soil water content during the irrigation period are analyzed. The soil surface water content reaches the maximum on the first day after irrigation. The water moisture at the 0–60 cm layer gradually decreases with the temporal variation after irrigation. Subsequently, the variation range of soil moisture decreases with the increase in soil depth. The soil moisture above 60 cm is greatly affected by meteorological factors, while the soil moisture below 60 cm is mainly influenced by water redistribution and water absorption by roots (Figure 5).

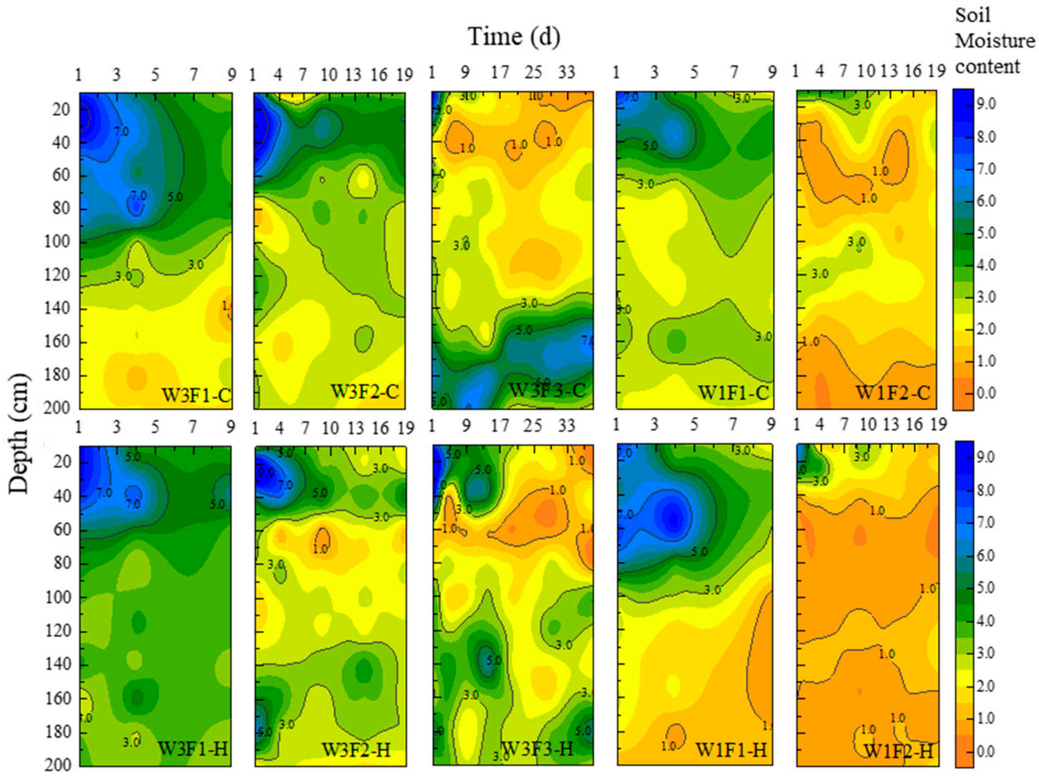

Figure 5. Temporal variation in soil moisture content in different treatments. The soil moisture content in the low (W1), medium (W2), and high (W3) irrigation amounts. F means irrigation frequency with F1 = 10 d, F2 = 20 d, F3 = 40 d. C and H represent *C. mongolicum* and *H. ammodendron*, respectively.

Therefore, the soil is divided into two layers for analysis: 0–60 cm (shallow layer) and 60–200 cm (deep layer). The soil water content of 0–60 cm is significantly greater than that of 60–200 cm and decreases rapidly after irrigation, with a decrease rate greater than the soil water content for 60–200 cm. The F1 and F2 irrigation periods decrease rapidly at 1–9 d after irrigation, and the decline rate of deep soil water content is slow or unchanged on the ninth day. The water content in the shallow and deep soil is similar. The treated soil water content under the F2 irrigation period is in a slow decline period at 9–19 d. The soil moisture in the shallow layers under the F3 treatment decreases rapidly during 1–4 d, decreases slowly during 4–9 d, and remains relatively stable in both the shallow and deep layers during 9–39 d (Figure 6).

3.3. Response of Soil Moisture to Irrigation Regime in Different Months

One-way ANOVA is used to compare the soil moisture content at 0–300 cm under different treatments in the same month from the 0–300 cm layer on 22 May, 12 July, 20 August, and 20 September 2016. As shown in Figure 7, the soil water content of *Calligonum mongolicum* and *Haloxylon ammodendron* at 0–300 cm decreases from May to July, and increases from July to September. The lowest water content is observed in July, while the highest is in September.

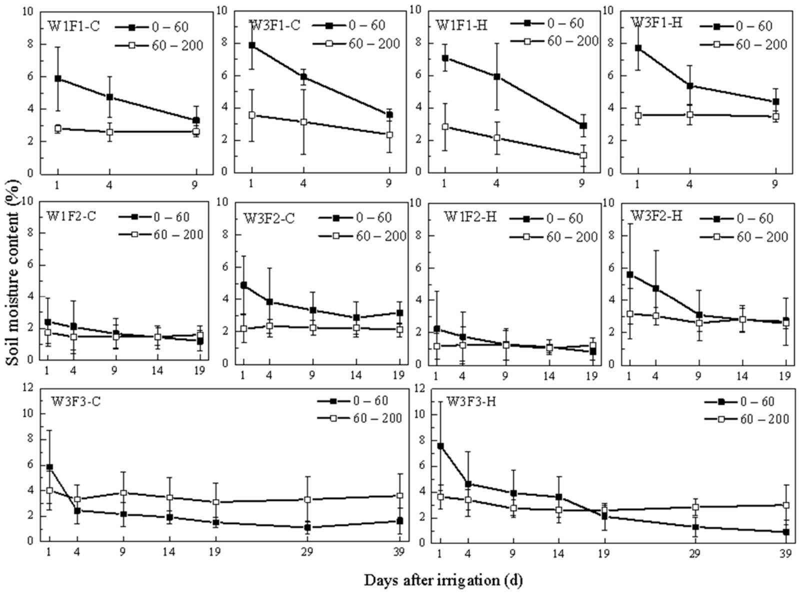

Figure 6. Variation in soil moisture content with the number of days after irrigation.

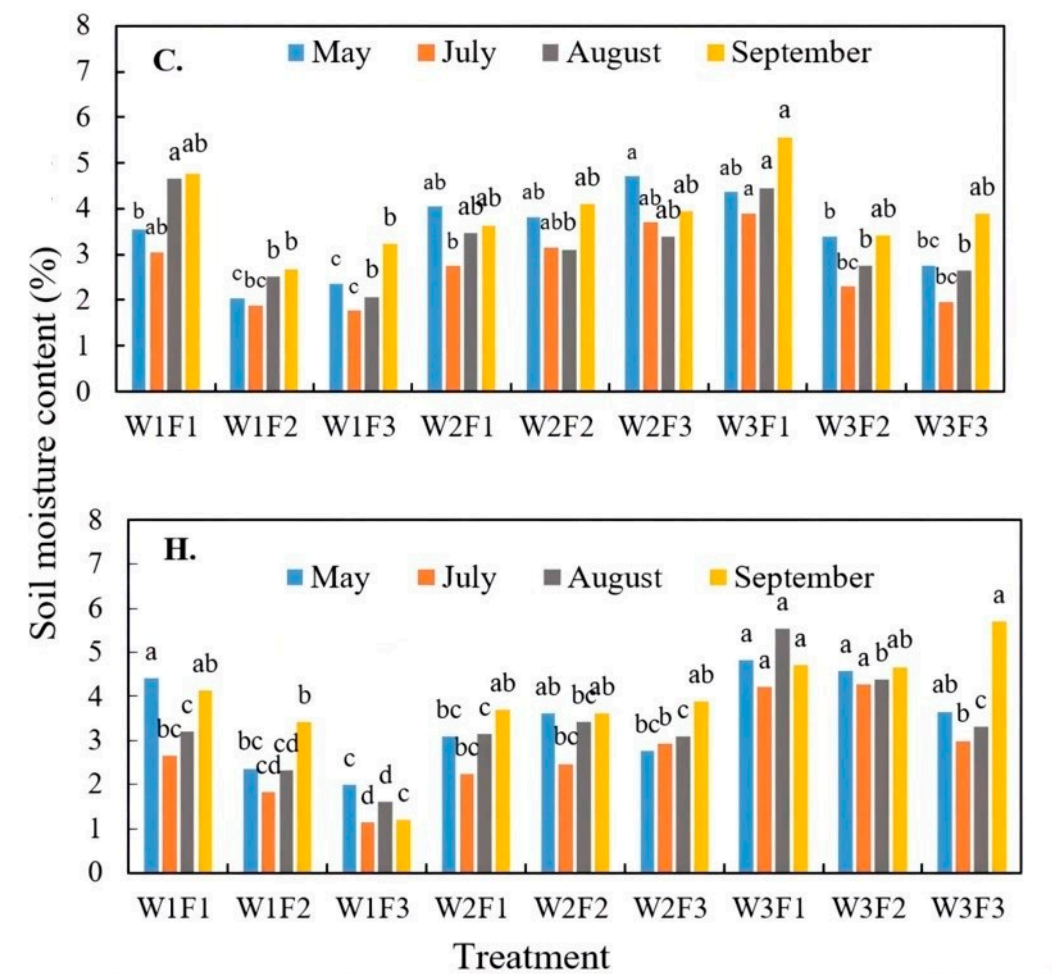

Figure 7. Monthly changes in soil moisture content at 0–300 cm under different treatments. (Lowercase letters indicate differences between treatments in the same month. The markers (a, b, c) with different letters differ significantly ($p < 0.05$) according to Least Significance Difference test).

Table 3 shows the differences in soil water storage between May and September at the 0–300 cm soil layer under each treatment. The water storage of *Calligonum mongolicum* at 0–100 cm increases, except for the W2F3 treatment. The water storage at 100–200 cm increases by 2.26 mm only in the W3F3 treatment, while values for other treatments decrease. The water storage at 200–300 cm increases slightly under the W3F1 and W3F2 treatments, but decreases under other treatments. The difference in water storage at 0–300 cm is F1 > F3 > F2, which are all positive values. Under W2 treatment, the water storage is F2 > F1 > F3, and the water storage is reduced under the W2F1 and W2F3 treatments.

Table 3. Differences in soil water storage between May and September at 0–300 cm soil layer under each treatment (C and H refer to *Calligonum mongolicum* and *Haloxylon ammodendron*, respectively).

Treatment	Difference in Soil Water Storage in September and May (mm)			
	0–100 cm	**100–200 cm**	**200–300 cm**	**0–300 cm**
W1F1-C	51.00	−8.03	−6.62	36.35
W1F2-C	26.71	−3.88	−3.75	19.08
W1F3-C	34.13	−2.22	−5.70	26.21
W2F1-C	7.47	−10.02	−9.44	−11.99
W2F2-C	26.59	−4.44	−13.93	8.22
W2F3-C	−10.95	−3.58	−8.28	−22.81
W3F1-C	34.62	−2.94	4.70	36.37
W3F2-C	4.72	−6.12	1.80	0.40
W3F3-C	31.66	2.62	−0.45	33.83
W1F1-H	−15.54	0.12	6.70	−8.72
W1F2-H	−13.64	23.99	21.04	31.40
W1F3-H	−5.12	−16.35	−2.72	−24.19
W2F1-H	32.22	−11.46	−2.56	18.20
W2F2-H	−8.66	10.34	−1.18	0.50
W2F3-H	36.16	−8.07	5.96	34.05
W3F1-H	14.64	−12.45	8.41	10.60
W3F2-H	4.10	−8.50	7.00	2.60
W3F3-H	15.81	17.32	17.68	50.81

The water storage of *Haloxylon ammodendron* at 0–100 cm decreases under the W1F1, W1F2, W1F3, and W2F2 treatments, while values for the other treatments increase. At 100–200 cm, the water storage volume increases under the W1F1, W1F2, W2F2, and W3F3 treatments. The other treatments' values are reduced. The water storage from 200 to 300 cm is reduced under the W1F3, W2F1, and W2F2 treatments, while values for all other treatments increase. The water storage difference of *Haloxylon ammodendron* at 0–300 cm is F3 > F1 > F2 under W2 > W3 irrigation amount, which are positive values. Under the W1 irrigation amount, the water storage difference is F2 > F1 > F3, and the treatment for W2F3 has a higher value than that for W2F1.

4. Discussion

In arid and semi-arid regions, the water resources directly affect the distribution and growth of plants. In the Taklimakan Desert, the climate is extremely dry, and the annual precipitation (36.6 mm) is far from sufficient to meet the evapotranspiration demand (3638.6 mm). The groundwater depth is more than 10 m, the replenishment effect of groundwater on soil water is negligible, and the main source of soil water is irrigation water [1]. The plants are facing the danger of long-term water shortage. After the Taklimakan Desert Highway shelterbelt was built, the tree species in the shelterbelt were mainly salt-tolerant. The water for plant growth came from underground high-salinity water drip irrigation. At present, although the current drip irrigation system can basically satisfy the growth of tree species in the shelterbelt, the utilization efficiency of plants for irrigation water is low [2].

The study of a reasonable saline irrigation becomes the basis of shelterbelt management and its sustainable existence.

In this study, the water supply rate is specific, and soil water infiltration is determined by soil water infiltration capacity, which is associated with soil wetness and porosity [20,21]. The surface soil moisture content is low from June to early August, resulting in slow transverse water transfer and little change due to intense surface evaporation. The growth of plant roots increases the non-capillary pores, improves the soil water conductivity, and lays a foundation for efficient soil water transport and storage [22]. Due to the downward growth of plant roots and the formation of soil macropores, the irrigation water can quickly reach the deep soil, causing periodic changes in soil water content. The lower limit of soil water evaporation is 40–60 cm, and excessive surface water content increases water evaporation, which is not conducive to water storage. The deeper the soil layer, the lower the soil moisture. Affected by atmospheric evaporation and water absorption by plant roots, the soil water storage variation coefficient is smaller. The results are consistent with the previous studies, such as Li et al. [1] and Zhang et al. [2].

After irrigation, the variation in soil water can be divided into a period of rapid water decline, slow water decline, and a relatively stable water level. Due to the loose soil in the sandy land, the shallow soil water can quickly infiltrate after irrigation. Subsequently, the strong evaporation effect leads to a dry sand layer forming on the soil surface, which significantly inhibits soil moisture evaporation [23]. The water absorption of plants mainly causes a decrease in soil moisture. When the soil moisture is relatively stable, soil moisture at the 0–200 cm layer cannot meet the needs of plant growth, and the water demand of plants mainly comes from the deep soil water supply, while soil moisture maintains a relatively stable state [2].

We noted the largest differences in soil water content between the two plant types in July, followed by August, May, and September. Soil water dissipation mainly includes soil evaporation and plant transpiration. In July, the temperature is the highest, and the water requirement for plant transpiration and soil evaporation is the largest, so the difference between treatments is the largest. In September, the temperature decreases, plant growth slows down, the water requirement decreases, and the difference between treatments is the least.

Under the irrigation regime with a 35 mm irrigation amount, the plants grow well, and part of the soil evaporation is reduced by shading. Irrigation can not only meet the needs of plant growth but also replenish soil water. Under the irrigation regime with a 17.5 mm irrigation amount, the plant growth is weakened due to drought stress in the early stage, although the irrigation amount is small. The leaf transpiration and root water absorption are reduced, and water dissipation is weakened. Moreover, insufficient soil water partially inhibits soil evaporation [24]. Therefore, this study highlights that an irrigation regime with a 35 mm irrigation amount is beneficial to soil water storage. More irrigation water will infiltrate into the deep soil, which will not be absorbed and utilized by plants, resulting in water waste. Increasing the single irrigation amount and prolonging the irrigation period can allow the more effective use of irrigation water. This study highlights that saline groundwater irrigation provides potential advantages for desert plants' survival under reasonable irrigation regimes.

The saving of water and improvement of water use efficiency are undoubtedly fundamental problems associated with such drought regions to avoid lowering the groundwater levels and to prevent ecological degradation. Although desert plants have strong resistance to water and saline stresses and different stress adaptation mechanisms at different growth stages [25], this study evaluated water dynamics and irrigation regimes only under preset irrigation combinations. Further work should conduct additional studies to examine whether or not an appropriate smaller amount of repeated irrigation will increase the water use efficiency of plants and reduce the ineffective evaporation of water. In addition, soil water infiltration and evaporation lead to salinity storage in the soil. The presence and accumulation of salinity affect plants' physiological ecology. The plants' adaptation to saline water irrigation and their responses to the different irrigation regimes should be considered in a future study.

5. Conclusions

Based on a field test of precision irrigation control in the Taklimakan Desert Highway shelterbelt, this study examined the effects of irrigation regimes on the soil water dynamics of two typical woody halophyte species (*Haloxylon* and *Calligonum*), and quantified the irrigation intervals and periods. The effects of saline water irrigation regimes on the soil water dynamics of two typical woody halophyte species (i.e., *Calligonum mongolicum* and *Haloxylon ammodendron*) show that:

(1) Their soil water content at 100–200 cm is significantly greater under the irrigation regime with a 17.5 mm irrigation amount than that under a 35 mm irrigation amount. Increasing the amount of water for single irrigation and prolonging the irrigation period will lead to more effective irrigation water use. After irrigation, the change in soil moisture of the two species in the shallow 0–60 cm layer can be divided into a rapid decline period (1–9 d), a slow decline period (9–19 d), and a relatively stable period (19–39 d). The decrease rate of soil moisture at 0–60 cm depth is significantly higher than that at 60–200 cm depth. The soil moisture below 200 cm replenishes the soil moisture below 60 to 200 cm.

(2) From May to July, the plant growth is vigorous and the temperature gradually increases, and the soil water is in the net consumption stage. The plant growth rate slows down from July to September, and the temperature decreases. The soil water is in the net replenishment stage; the difference in soil water content between 0 and 300 cm is the largest in July and August and the smallest in September.

(3) The irrigation regime combining a 35 mm irrigation amount with 10 days benefits soil water storage and water content with respect to *Calligonum*, while the irrigation regime combining a 35 mm irrigation amount with 40 days is best for *Haloxylon*.

This study highlights that saline groundwater irrigation is advantageous for supporting desert plants' survival and preventing ecological degradation under reasonable irrigation regimes. Future work should focus on the plants' adaptation to saline water irrigation and their responses to the different irrigation regimes and water-saving irrigation measures in the desert shelterbelt construction.

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