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Effects of natural covers on soil evaporation of the shelterbelt along the Tarim Desert Highway

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The control of soil evaporation is one of important approaches to save water. The artificially simulated evaporation experiments have been conducted in the hinterland of the Taklimakan Desert to reveal the effects of the natural covers on the soil evaporation of the Tarim Desert Highway shelterbelt as well as provide some insights in the efficient utilization of water resources and optimization of irrigation systems. The results showed that (1) All the covers, including the sand deposit, the salt crust, the litter, the sand-litter mixed layer and so on, can significantly inhibit the soil water evaporation. Specifically, the daily evaporation, the total evaporation, and the evaporation rate in covered sands were much smaller than that of sands without cover. The cover inhibition effects increased with the cover thickness. Particularly, the soil evaporation of the covered sands was less affected by external and internal factors than that of the bare sands. Moreover, the variation of daily evaporation of covered sands was smaller than that of bare sands. The cumulative evaporation varied linearly with time in the covered sands whereas it varied logarithmically in the bare sands. In addition, the soil evaporation in the bare sands showed significantly different characteristics in the early and late stages of the evaporation. (2) All the covers exhibited the significant inhibiting effect on the soil evaporation, and the inhibition efficiency increased logarithmically with the cover thickness. However, as the cover thickness was above a certain value, the increase in the inhibition efficiency was slow. Particularly, at a cover thickness of 2 cm, there was no obvious difference in the inhibition efficiency among all kinds of covers. The maximum inhibition efficiency as calculated from the daily evaporation on the first day of irrigation was: sand-litter mixed layer (79.92%) > litter layer (78.96%) > salt crust (75.58%) > sand bed (74.11%), whereas the average inhibiting efficiency as calculated from the cumulative soil evaporation at the end of an irrigation cycle (the fourth day) was: salt crust (67.78%) > sand-litter mixed layer (66.72%) > sand deposit (63.28%) > litter layer (61.74%).

Taklimakan Desert, shelterbelt irrigation, cover, soil evaporation, inhibition efficiency

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The water shortage is the main problem for large-scale forestation in arid zones[1]. Moreover, as a result of high evaporation rates, some soil moisture may lost[2] and lead to a strong aggregation of soil salt at soil surface[3]. The Taklimakan Desert is extremely droughty, and in particular, the Tarim Desert Highway shelterbelt is irrigated with saline phreatic water[4]. As a result, after irrigation, a crust with a high salt content can be formed at soil surface[5,6]. Particularly, precipitation may lead to the salt dissolution near the soil surface and transport the dissolved salts to plant roots. The leading salt stress can cause the death of young plants as well as the plants with shallow root system[7]. Therefore, reducing soil water evaporation is a key to solve all of these problems.

Currently, the technologies effective in reducing soil water evaporation have been actively studied and developed all over the world[8–15], including covering by straw or plastic film, spraying chemicals such as evaporation inhibitor, irritation inducting to the root zone, etc. Among these technologies, covering by straw or plastic film is more mature and has wide application. However, because of the large area of the Tarim Desert Highway shelterbelt (3128 hm^2 with 436 km in length and 72－78 m in width) together with frequent blown sand activities as well as complex terrain[16], all of these technologies show a high investment cost thereafter little practical value. In contrast, there have been natural covers, including the sand deposits, the salt crust, litter, and the sand-litter mixed layers, formed in the Tarim Desert Highway shelterbelt. They may play some roles in inhibiting the soil water evaporation. In this paper, we studied the effects of various natural covers on the evaporation and inhibition of soil water by means of artificially simulated experiments, aiming at providing some scientific insights in the effective utilization of water resources as well as the optimization of irrigation systems.

1 Experimental site

All experiments were conducted in the Tazhong Botanical Garden located in the hinterland of the Taklimakan Desert (38°58′N, 83°39′E) with annual average temperature of 12.4℃, the maximum temperature of 45.6℃, and the minimum temperature of –22.2℃. The average relative humidity, the annual precipitation, and the annual evaporation of the Tazhong Botanical Garden was 29.4%, 11.05 mm, and 3638.6 mm (300 times more than the rainfall), respectively. The average wind speed was 2.5 m/s, and the maximum instantaneous wind speed is 20.0 m/s[17]. The characteristics of soil varied significantly with the surface features. Most soils were blown sand soil with a salt content of 1.26－1.63 g/kg[18,19]. The mineralized degree of groundwater was 4.04 g/L[20]. In addition, the natural plant diversity was poor with only 9 species. The community structure was simple, and the vegetation coverage was extremely low[21].

2 Experimental method

2.1 Experimental materials and instruments

Based on the soil evaporation theory [22] and methods in the literature[23–26], the experiments were conducted by a homemade Micro-lysimeter. The micro-lysimeter consisted of two concentric cylindrical barrels made of white PVC. The inner barrel is the trial barrel with an inner diameter of 10 cm; the outer barrel is the protection barrel whose inner diameter is 15 cm. The bottom of both inner and outer barrels was sealed by adhesive tapes and plastic thin films, while the top of both barrels was open. The height of barrels varied with the experiments, whereas the thickness of wet sand bed under the cover was kept at 10 cm.

The soil samples were mobile blown sand, the most common sand along the desert highway, which was made mainly of fine sand and very fine sand. The moisture content of the mobile blown sand was as low as 0.02%, and its capillary porosity was 35.64%. The moisture retention capacity of mobile blown sand was low: the saturation moisture capacity and capillary moisture capacity were 27.03%, 25.64%, respectively. In addition, the mobile blown sand was weak alkaline whose pH value was 8.73 (Table 1).

2.2 Experimental procedure

The sand sample was first fully mixed, dried, and sieved to remove undesired impurities, and then uniformly packed into the inner barrel of the Micro-lysimeter. According to the saturation moisture capacity, a certain amount of fresh water was added into the sample to saturate the sand bed (Salts can accumulate at the soil surface and lead to the formation of salt crusts, which may somehow affect the soil evaporation. Therefore, fresh water was used here to avoid such effects). Then, the wet sand bed was covered by some materials. Finally, the inner barrel that contained the sample was placed

Table 1 Some basic physical properties of the soil in the study area

Moisture physical properties (%)	Natural moisture content	Saturation moisture capacity	Capillary moisture capacity		Total porosity	Capillary porosity
	0.02	27.03	25.64		37.58	35.64
Main chemical properties	pH (1 : 5)	Total salt content ($g\cdot kg^{-1}$)			Electric conductivity ($ms\cdot cm^{-1}$)	
	8.73	1.51			0.49	
Physical composition (%)	<5 μm	5－63 μm	63－125 μm	125－250 μm	250－500 μm	>500 μm
	0.27	12.35	52.04	30.79	2.12	2.42

into the outer barrel buried into the earth with its upper end just above the ground surface. The inner barrel was weighed daily at 18:00 by a balance of 0.01 g resolution and 3600 g weight range (LP3102, Sartorius), and the soil moisture evaporation was calculated.

The experiment started in October 2006 at the bare sand in the Tazhong Botanical Garden. During the experiment period, there were no dust storms, precipitations, and other special weather events; the average wind speed was 1.40 m/s^{-1}, the daily and monthly average temperature was 10℃－24℃ and 16.7℃, respectively.

2.3 Experimental design

Based on the type of natural cover in the Tarim Desert Highway shelterbelt, four groups of experiments, i.e., the sand deposit group, the salt crust group, the litter group, the sand-litter mixed layer group, have been set up. The control experiment for each group has been conducted in the bare sand under the same experimental conditions. Each experiment at specific conditions has been repeated for three times (see Table 2 for details).

The inhibition efficiency of soil water evaporation is an index to measure the ability of a specific cover to inhibit the soil water evaporation, it is calculated by

$$I_E = (E_{Ck} - E_T)/E_{CK}\times 100, \quad (1)$$

in which I_E is the inhibition efficiency, E_T is the soil water evaporation after a specific treatment, E_{CK} is the soil moisture evaporation of the control.

3 Results and discussions

3.1 Effects of covers on soil water evaporation

The experimental results showed that the daily average evaporation of the soil under the covers was smaller than that of the control. Moreover, as revealed by the daily evaporation data in both experiment and control group, the evaporation process of soil water can be divided into two stages (Table 3), and in particular, the daily evaporation of control was larger than that of covered soil in the first stage, whereas smaller in the second stage (but

Table 2 Experimental design

Type of covers	Experimental treatment	Abbreviation	Duration (d)
Sand deposit (S)	6 kinds of treatments: thickness 2, 4, 6, 8, 10 cm, contrast, 3 repeats for everyone	CK, S1, S2, S3, S4, S5 represents contrast (no cover, similarly hereinafter), 2, 4, 6, 8,10 cm thick, height of lysimeter 10, 12, 14, 16, 18, 20 cm, thickness of sand substratum 10 cm, fresh water 250 mL	21
Salt crust (C)	2 kinds of treatments: thickness: 2 cm, 3 repeats for everyone	CK, C represents contrast, 2 cm thick, height of lysimeter 10 cm, 12 cm, thickness of sand substratum 10 cm, fresh water 250 mL	14
Litter (L)	6 kinds of treatments: thickness 1, 2, 3, 4, 5 cm, contrast, 3 repeats for everyone	CK, L1, L2, L3, L4, L5 represent contrast 1, 2, 3, 4, 5 cm thick, height of lysimeter 10, 11, 12, 13, 14, 15 cm, thickness of sand substratum 10 cm, fresh water 250 mL	23
Mixed layer (M)*	4 kinds of treatments: thickness 2, 4, 6 cm, contrast, 3 repeats for everyone	CK, M1, M2, M3 represents contrast 2, 4, 6 cm thick, height of lysimeter 10, 12, 14, 16 cm, thickness of sand substratum 10 cm, fresh water 250 mL	14
Different cover	5 kinds of treatments: sand deposit, salt crust, litter, sand-litter mixed layer, contrast, 3 repeats for everyone	CK, S, L, C, M represents contrast, sand deposit, litter, salt crust, sand-litter mixed layer, 2 cm thick, height of lysimeter 10, 12 cm, thickness of sand substratum 10 cm, fresh water 250 mL	14

* 1. The salt crust cover was obtained around emitters of the shelterbelt. The litter cover was prepared from the air-dried pieces (1 cm long) of assimilating branches of *Calligonum*. The sand-litter mixed layer was prepared by alternatively layering of the sand deposit and assimilating branch of *Calligonum*. 2. The evaporation experiments in the salt crust, the litter, and the sand-litter mixed layers at different cover thickness were conducted simultaneously, so the same control was adopted.

Table 3 Characteristics of evaporation among all experiment settings soils

Types of covers	Experiment settings	Variation characteristics of daily evaporation ($kg \cdot m^{-2}$)					Cumulative curve of evaporation		
		Average	Amplitude	Standard deviation	Variation coefficient	Periodicity	Types of curve	Gradient: Surge segment	Gradient: Stable segment
Sand deposit layer	CK	1.70	5.75	1.71	1.00		Logarithmic curve	4.94	0.24
	S1	1.11	0.92	0.16	0.14	1−6 d CK>S_i		0.92	
	S2	0.56	0.89	0.14	0.25			0.49	
	S3	0.31	0.49	0.10	0.31		Approximate straight line	0.27	
	S4	0.18	0.30	0.05	0.27	7−21 d CK< S_i		0.16	
	S5	0.09	0.20	0.04	0.39			0.09	
Salt crust layer	CK	2.89	4.81	1.50	0.52	1−14 d	Logarithmic curve	4.92	1.17
	C	0.93	0.63	0.16	0.17	CK>C	Approximate straight line	0.90	
Litter	CK	2.42	7.98	2.15	0.89		Logarithmic curve	5.54	0.28
	L1	1.71	1.42	0.31	0.18	1−8 d CK>L_i		1.36	
	L2	1.48	1.41	0.25	0.17			1.19	
	L3	1.27	1.46	0.24	0.19		Approximate straight line	1.03	
	L4	1.13	1.45	0.24	0.21	9−23 d CK<L_i		0.91	
	L5	0.96	1.29	0.23	0.23			0.77	
Sand deposit-litter mixed layer	CK	2.89	4.81	1.50	0.52	1−12 d	Logarithmic curve	4.92	0.68
	M1	0.96	0.50	0.13	0.14	CK>M_i		0.97	
	M2	0.71	0.37	0.09	0.12	13−14 d	Approximate straight line	0.72	
	M3	0.49	0.31	0.07	0.14	CK<M_i		0.49	
Different covers	CK	2.89	4.81	1.50	0.52	1−12 d	Logarithmic curve	4.92	0.68
	S	1.06	0.61	0.13	0.12	CK>All		1.13	
	C	1.06	0.55	0.16	0.15		Approximate straight line	1.04	
	L	0.93	0.63	0.16	0.17	12−14 d		0.99	
	M	0.96	0.50	0.13	0.14	CK< All		0.97	

the daily evaporation of the soil under the salt crust was always smaller than that of the control). However, the variation amplitude, the standard deviation, and the coefficient of variation in control groups were far larger than those of covered soils (Table 3), indicating that illustrated the covered soils are less vulnerable to both external factors such as the weather and internal factors such as the soil moisture than the control. Furthermore, both the amplitude and standard deviation of daily soil evaporation decreased with the thickness of cover. It indicated that the thicker the cover was, the less the soil evaporation was affected by both external and internal factors (Table 3). It can conclude that the cover thickness may have significant effects on the process of soil water evaporation. Finally, the variation amplitude of daily evaporation followed the sequence M <C <S <L. Specifically, the soil covered by the sand-litter mixed layers was least affected by both external and internal factors while the soil covered by the litter was affected most. The soil covered by the sand deposit was more vulnerable than that under the salt crust. This may be related to the structure and composition of covers.

In all control groups, the cumulative evaporation curves followed a logarithmic distribution. The daily evaporation decreased over time and approached to a constant value. Particularly, the slope of cumulative evaporation curve as well as the daily evaporation was large in the early stage of the experiments and became small in the intermediate and late stage of the experiments. In contrast, when the soil surface was covered, the daily evaporation was small and varied smoothly over the entire experimental period, while the cumulative evaporation curve varied linearly with a small slope value (Table 3). Although the cumulative evaporation curves varied linearly for all the cover thicknesses, the slope decreased with the thickness exponentially (Table 3), indicating that the rate of daily average evaporation decreased exponentially with the cover thickness.

3.2 Inhibiting effects of covers on soil evaporation

3.2.1 Inhibiting effects of sand deposit on soil evaporation. The daily evaporation of the soil under sand cover was much smaller than the control during the first seven days. However, during the period of 8th day to the end of the experiment (the 21st day), the daily evaporation of the covered soil became gradually larger than that of the control, and the control only maintained a small daily evaporation (Figure 1(a)). In addition, the daily evaporation of the covered soil decreased with the cover thickness. It indicated that the sand deposit could decrease the soil water evaporation and most effective in the early stage of irrigation (in the intermediate and late stage of irrigation, the daily evaporation was large because of the high water content of the soil). However, as shown by the cumulative evaporation curve, there was a clear inhibition of evaporation of the covered sand (Figure 1(b)).

Specifically, on the first day of the experiment, in which the soil moisture was the highest and evaporated under the sufficient water supply condition, the inhibiting effect of sand cover was obvious and increased with the thickness of the dry sand cover. I_E of samples S1, S2, S3, S4 and S5 was 82.92%, 97.78%, 98.71%, 99.26%, and 99.58%, respectively. Particularly, I_E increased logarithmically with the sand thickness D_S (R^2 = 0.79, F = 11.39, P = 0.043). On the seventh day of the experiments, there was still the obvious inhibiting effect on the soil evaporation, even though the soil moisture was small. I_E still increased logarithmically with the sand thickness D_S (R^2=0.97, F = 112.65, P = 0.002), but the inhibition efficiency of the cover was much lower than that in the first day. The inhibiting effects became less obvious since the eighth day of the experiment. However, the sand deposit still showed an overall inhibition on the evaporation, as shown by the cumulative evaporation. Specifically, I_E was found to be 67.73%, 81.86%, 89.18%, and 94.57% for S1, S2, S3, S4 and S5, respectively, increasing with D_S logarithmically (R^2 = 0.98, F = 141.39, P = 0.001).

3.2.2 Inhibiting effects of salt crust on soil evaporation. As shown in Figure 2(a), except for the thirteen day, the daily evaporation of the soil under the salt crust was smaller than that of control during the entire experiment period. In particular, in the early stage of the experiment, i.e., from the first day to the eighth day, the difference was large (1.99－4.20 $kg \cdot m^{-2}$) while it was small (0.02－1.69 $kg \cdot m^{-2}$) in the late stage (the 9th day－14th day). In addition, the cumulative evaporation of the covered soil was much smaller than the control, as shown in Figure 2(b).

Specifically, during the early stage, in which the soil water content was highest and evaporated under a condition close to that of sufficient water supply, the inhibiting effect of salt crust was most obvious. All inhibiting efficiencies were above 62%, and the maximum value was as high as 78.03% (the 5th day). However, in the intermediate and late stage, because of the decrease in

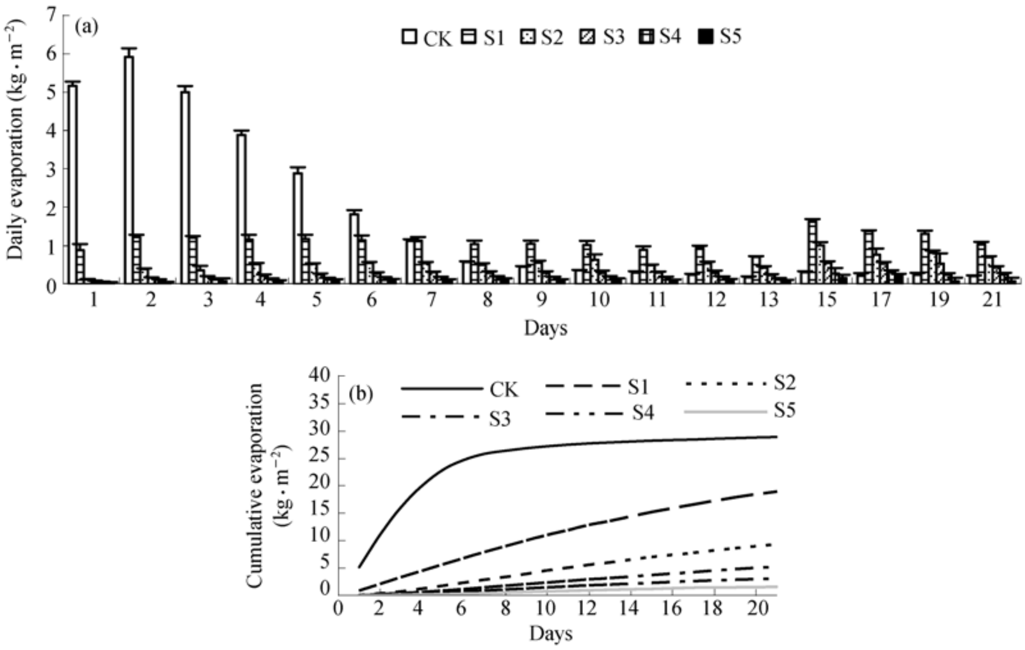

Figure 1 The variation of the daily evaporation (a) and cumulative evaporation (b) of soil covered with sands.

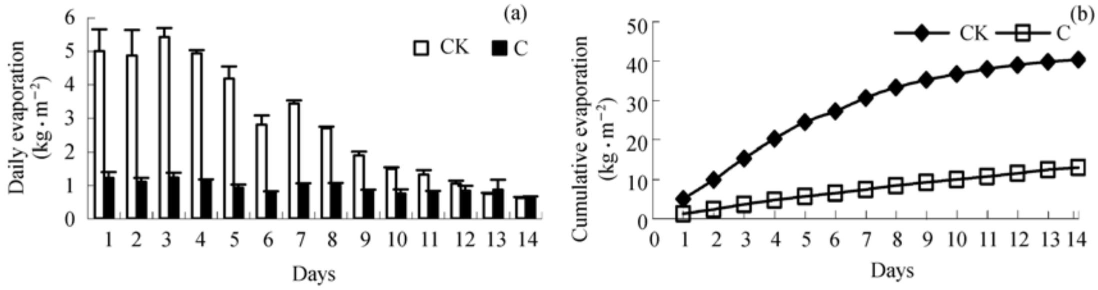

Figure 2 The variation of the daily evaporation (a) and cumulative evaporation (b) of salt crust covered sand.

the soil water content, the inhibiting ability as well as the efficiency became less significant. However, the overall inhibition efficiency over an irrigation cycle was not small, as shown by the high value of average I_E (67.78%), which was calculated from eq. (1).

3.2.3 Inhibiting effects of litter on soil evaporation. As shown in Figure 3(a), the daily evaporation of the soil under the litter cover was much smaller than that of control and showed an obvious inhibition on the evaporation during the first eight days. Form the 9th day to the 11th day, the inhibition on the evaporation gradually decreased in the control, and the daily evaporation of L1—L4 samples became larger than the control. However, from the 9th day to the 23rd day of the experiment, there was only small daily evaporation of the control and even smaller in the soils under the litter cover. In addition, the daily evaporation of the covered soil decreased with the cover thickness during the entire experiment period. Finally, the inhibiting effect of the litter on the evaporation can be seen more clearly from the soil cumulative evaporation curve (Figure 3(b)).

On the first day when the soil water supply was sufficient, the litter cover exhibited the most obvious inhibition on the evaporation. The inhibition efficiency was 73.15%, 78.23%, 83.90%, 85.53% and 86.66% for 1 cm, 2 cm, 3 cm, 4 cm and 5 cm litter thickness, respectively. Particularly, I_E increased logarithmically with D_L (R^2=0.9797, F = 144.02, P= 0.001), indicating that I_E did not increase linearly with D_L and in particular varied slowly above a certain D_L value. On the 8th day of the experiment, there was still significant inhibiting effect on the evaporation of covered soil, even though the soil water content decreased and the water supply for evaporation was less sufficient. Moreover, I_E still increased logarithmically with D_L (R^2 = 0.977, F = 127.62, P = 0.001). After the 9th day, because of the decrease in the water content as well as the evaporation of the bare sand, the inhibiting effect of the litter cover on evaporation became less significant. However, there was still an overall inhibition of the little cover on the evaporation during the entire experiment period, as shown clearly by the cumulative soil evaporation curve. Moreover, I_E was

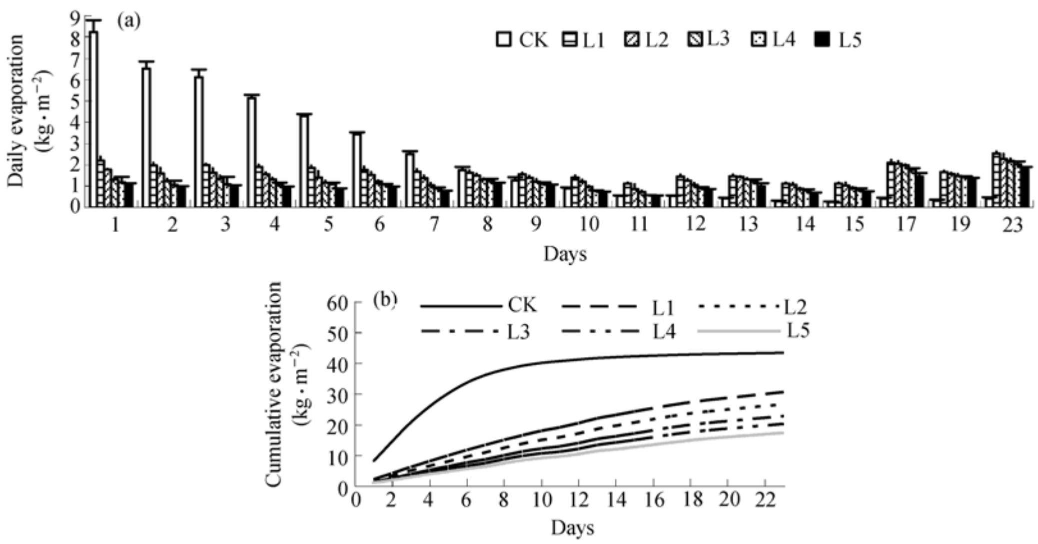

Figure 3 The variation of the daily evaporation (a) and cumulative evaporation (b) of litter covered sand.

29.49%, 38.63%, 47.44%, 53.36%, and 60.16% for 1 cm, 2 cm, 3 cm, 4 cm and 5 cm litter thickness, respectively. In addition, I_E increased logarithmically with D_L (R^2 = 0.9401, F = 47.06, P = 0.006).

3.2.4 Inhibiting effects of sand-litter mixed layer on soil evaporation. As shown in Figure 4(a), during the first twelve days of experiment, the daily evaporation of the soil covered by the sand-litter mixed layer was much smaller than the control. However, on the 13th and 14th day, the daily evaporation of the control was smaller than that of M1 but still larger than M2 and M3. In addition, during the entire experiment period, the daily evaporation of covered soil decreased with the cover thickness. All of these results clearly indicated that the sand-litter mixed layer could effectively reduce the soil evaporation, and the inhibiting effects can be well revealed also by the curve of cumulative evaporation (Figure 4(b)).

On the first day of the evaporation, on which the soil water content was high, the inhibition efficiency was the largest, and in particular, I_E was as high as 79.92%, 85.74% and 87.23% for M1, M2 and M3, respectively. In addition, I_E increased logarithmically with D_M (R^2 = 0.9683, F = 30.38, P =0.114). In contrast, in the intermediate and late stage of the experiment, the water content in the soil decreased gradually. As a result, the water supply for the evaporation became less sufficient. The inhibition effect of the sand-litter mixed layer on the evaporation was less significant. Particularly, on the 8th day, I_E still increased logarithmically with D_M (R^2 = 0.774, F = 3.42, P =0.315). However, the cover still exhibited an overall significant inhibition on the evaporation, as shown by the curve of cumulative soil water evaporation. The average I_E was 66.72%, 75.24%, and 82.89% for M1, M2 and M3, respectively, and increased logarithmically with D_M (R^2=0.9858, F = 69.96, P = 0.076).

3.2.5 Comparisons of inhibiting effects of different covers on soil evaporation. During the first twelve days of experiment, all covered soils showed smaller daily soil evaporation than the control, and exhibited an obvious inhibition on the evaporation, which was particularly significant during the first nine days. However, on the 13th and 14th days, the daily evaporation of all covered soils was larger than the control (Figure 5(a)) while different covers still exhibited an obvious inhibition on the evaporation, as shown clearly by the cumulative soil water evaporation (Figure 5(b)).

On the first day of the experiment, on which the soil water content was the highest and the soil water supply was the most sufficient, all covers showed the most significant inhibiting effect on the water evaporation. Moreover, in comparison with the control, the value of I_E of each cover followed M (79.92%) > L (78.96 %) > C (75.58%) > S (74.11%). The same conclusion can also be obtained from the value of evaporation rate, which can be evaluated from the slope of the cumulative evaporation by curve fitting (Table 3). Specifically, the evaporation rate followed S > C > L > M, indicating that I_E varied as M > L > C > S. However, when calculated from the cumulative evaporation over an irrigation cycle, I_E varied as C (67.78%) > M (66.72%) > S (63.28%) > L (61.74%) (Figure 6).

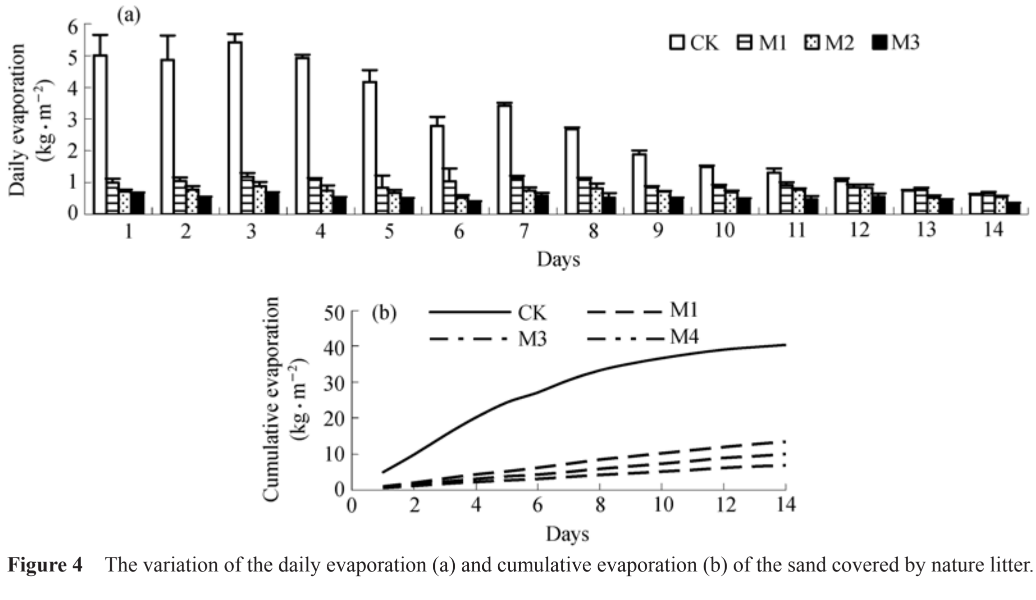

Figure 4 The variation of the daily evaporation (a) and cumulative evaporation (b) of the sand covered by nature litter.

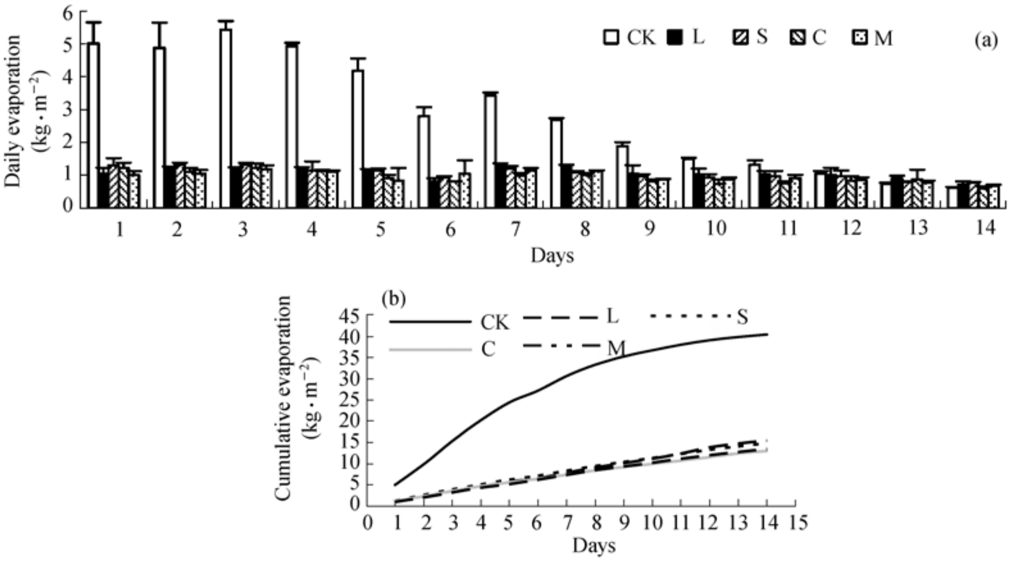

Figure 5 The variation of the daily evaporation (a) and cumulative evaporation (b) of soil under different covers.

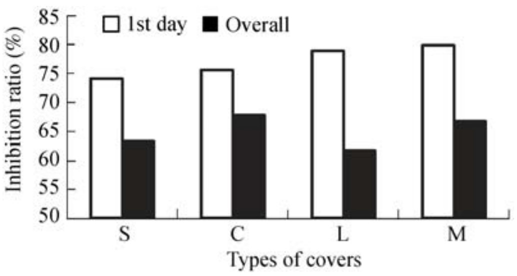

Figure 6 The comparison of inhibition efficiency of different covers on the soil evaporation.

4 Conclusions

Based on the analysis of experimental data of artificially simulated soil evaporation in the hinterland of the Taklimakan desert, we can conclude that:

(1) In extremely arid deserts, the water evaporation of bare sands was rapid and can be affected significantly by both external and internal factors, and in particular, the soil water retention. The soil evaporation behaved differently at the different stages. Specifically, in the earlier stage, the soil water content was high, and consequently, the daily evaporation was large; while in the intermediate and late stage, with the decrease in the soil water content, the daily evaporation decreased slowly to a small value. Particularly, the large variation in the daily evaporation of the bare sands during the experiment indicated that the soil evaporation may be influenced greatly by the weather conditions. In addition, the cumulative soil evaporation increased with time logarithmically. In contrast, compared to the bare sands, both the daily evaporation amount and rate, as well as the variation, were small in covered sands. Moreover, the variation in daily evaporation decreased as the cover thickness increased, indicating that the soil evaporation of covered sands was relatively less affected by the external and internal factors. Finally, the cumulative soil evaporation varied linearly in the covered sands.

(2) The sand deposit, salt crust, litter and sand-litter mixed layer all exhibited an obvious inhibition on the soil evaporation, reducing the evaporation rate and keeping a high water content. Particularly, the inhibiting effects increased logarithmically with the cover thickness, but became much slow and approached a certain limit when the cover thickness was above a certain value.

The largest inhibition efficiency can be approximately calculated from the daily evaporation on the first day. Specifically, for covers with a thickness of 2 cm, the I_E was: sand-litter mixed layer 79.92%, litter 78.96%, salt crust 75.58%, and sand deposit 74.11%; the real inhibition efficiency of cover on evaporation could be calculated according to the cumulative soil evaporation obtained at the end of irrigation cycle (14th day). Under the same thickness (2 cm) condition, the inhibition efficiency I_E was found to be 67.78%, 66.72%, 63.28%, and 61.74% for the salt crust, the sand-litter mixed layer, the sand deposit, and the litter, respectively.

Because of the special natural environment as well as the effective protection by the Tarim Desert Highway shelterbelt, both sand deposit and plant litter were accumulated within the shelterbelt every year. These accumulated substances can combine to form a sand-litter mixed layer, in which the plant litter and sands were bonded by salts and formed a salt crust with certain hardness. This led to the formation of a natural cover. From the experimental results about the inhibiting effect of covers on the soil evaporation reported here, we can infer that all covers played a role in inhibiting the soil water evaporation, and the inhibiting effects of these covers increased with their thickness, which increased as the trees in the shelterbelt grow. Consequently, the root-mixture can maintain a high soil water content. It can promote the forest growth, reduce the salt accumulation on the soil surface, and prevent forest from the damage of salt and precipitation. Therefore, because the natural covers in shelterbelts can effectively reduce the excessive soil water evaporation, and facilitate better growth of forest, effective measures should be taken to protect them. Moreover, some artificial measures should also be taken to built the artificial cover, reduce the soil water evaporation rate, and decrease the soil secondary salinization. Finally, we hope that the study about the inhibiting effect of the covers on the soil evaporation reported in this paper could provide some insights in balancing the soil moisture of the shelterbelt, as well as some information for optimizing the irrigation system of the shelterbelt.

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