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Dynamics and Distribution of Soil Salinity under Long-Term Mulched Drip Irrigation in an Arid Area of Northwestern China

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Abstract: Mulched drip irrigation has been widely used in agricultural planting in arid and semi-arid regions. The dynamics and distribution of soil salinity under mulched drip irrigation greatly affect crop growth and yield. However, there are still different views on the distribution and dynamics of soil salinity under long-term mulched drip irrigation due to complex factors (climate, groundwater, irrigation, and soil). Therefore, the soil salinity of newly reclaimed salt wasteland was monitored for 9 years (2008–2016), and the effects of soil water on soil salinity distribution under mulched drip irrigation have also been explored. The results indicated that the soil salinity decreased sharply in 3–4 years of implementation of mulched drip irrigation, and then began to fluctuate to different degrees and showed slight re-accumulation. During the growth period, soil salinity was relatively high at pre-sowing, and after a period of decline soil salinity tends to increase in the late harvest period. The vertical distribution of soil texture had a significant effect on the distribution of soil salinity. Salt accumulated near the soil layer transiting from coarse soil to fine soil. After a single irrigation, the soil water content in the 30–70 cm layer under the cotton plant undergoes a 'high–low–high' change pattern, and the soil salt firstly moved to the deep layer (below 70 cm), and then showed upward migration tendency with the weakening of irrigation water infiltration. The results may contribute to the scientific extension of mulched drip irrigation and the farmland management under long-term mulched drip irrigation.

Keywords: arid zone; soil salinity; long-term mulched drip irrigation; soil texture; cotton

1. Introduction

Soil salinization is a major obstacle to the sustainable development of irrigated agriculture. Ten percent of arable lands worldwide are affected by salinization, and 4 million km^2 of arable lands lose planting function due to salinization [1,2]. Secondary salinization has a more serious impact on agricultural development in arid and semi-arid areas, with salinization affecting 9–25% of cultivated land in Tunisia, the United States, India and South Africa. Xinjiang, Northwest China, suffers from severe soil salinity. Saline-alkali land in Xinjiang is accounting for nearly one third of the total saline-alkali land in China, and most of the saline-alkali lands are within the oasis [3]. Cotton, one of the main crops in Xinjiang, belongs to a salt-tolerant crop. The cotton tolerance to irrigation water salinity (electrical conductivity) and soil salinity (electrical conductivity) are 5.1 dS m^{-1} and 7.7 dS m^{-1} under 100% yield potential, while 18 dS m^{-1} and 27 dS m^{-1} under 0% yield potential [4]. The large area of severe saline-alkali land seriously restricts effective use of the land and the development of agriculture [5]. However, soil salt redistribution is accompanied by irrigation in arid areas, and different irrigation methods will lead to different water and salt transport and distribution [6]. On the one hand, irrigation water can leach the salt in the soil and dilute the concentration of the soil solution. On the other hand, unreasonable irrigation or poor drainage will result in a rapid rise of the groundwater table, which could lead to soil salinization. For irrigated areas in arid regions, secondary soil salinization is a high probability event under the combined action of groundwater level, groundwater mineralization, soil texture [7,8]. Therefore, effective tillage and irrigation methods are essential to mitigate the adverse effects of drought and soil salinity on crops.

As a new technique combining drip irrigation with film mulching, the mulched drip irrigation has been successfully applied in arid and semi-arid regions in China for more than 20 years [9]. The application area of mulched drip irrigation in Xinjiang has exceeded 2.0×10^6 ha, achieving remarkable economic and social benefits [10]. Drip irrigation keeps the soil in the crop root system moist and the soil in the crop rows relatively dry. This 'dry–wet' interface has a positive effect on regulating soil salinity change and redistributing water and salt. Moreover, mulched drip irrigation can improve soil structure, control temperature and humidity, and then affect the distribution of soil water and salt. Therefore, mulched drip irrigation has been widely used as one of the most suitable irrigation techniques for saline-alkali land [11–13]. Studies have shown that the soil in the cotton root zone generally shows desalination under mulched drip irrigation, but the depth of the desalted zone are different [10,14,15]. There are different views on the change and distribution of soil salinity with the years of mulched drip irrigation. Some studies show that under long-term mulched drip irrigation in cotton fields, the soil salinity in the 0–40 cm or 0–60 cm soil layer decreases year by year, and in some shallow groundwater areas even the whole unsaturated zone is desalted [10,16–18]. Other study suggests that under mulched drip irrigation, the soil within the film is in a state of desalination during the growth period of cotton, while after the growth period, soil salinity in the 0–60 cm layer increases, and the soil salinity increases as a whole with the continuous application of mulched drip irrigation [15]. Meng et al. [19] found that soil salinity decreased in the first three years of mulched drip irrigation, and then increased. Sampling and tracking observation on farmland under mulched drip irrigation were carried out for 5 years, which showed that soil salt did not accumulate significantly [20]. In addition, the distribution of soil salinity in arid areas is affected by many factors, such as groundwater level [21], groundwater salinity [22], irrigation system [11,23], and soil texture [24,25].

In general, previous research results indicate that mulched drip irrigation can provide the necessary soil and water environment for crop growth on saline-alkali land, which is beneficial to increase crop yield. Compared with surface irrigation, mulched drip irrigation has a significant water-saving effect, and plays a positive role in guiding the regulation of soil water and salt and improving saline-alkali land in different areas. However, a consistent conclusion about the long-term effects of mulched drip irrigation on soil salinity has not formed, and even contradictory conclusions were drawn in some studies. Thus, it is of great significance for agricultural development in arid and semi-arid regions to study the dynamics and distribution of soil salinity under long-term mulched drip irrigation.

This paper presents the change characteristics of soil salinity under long-term drip irrigation and the impact of soil texture and soil water on soil salinity, in order to provide a basis for soil salt management under long-term mulched drip irrigation in arid and semi-arid areas. The main objectives of this study were to: (i) investigate interannual changes and the characteristics of soil salinity change during the growth period in salt wasteland under long-term mulched drip irrigation; (ii) analyze the vertical distribution of soil salinity and its relationship with soil texture; (iii) characterize soil water and salinity distribution at different distances from the dripper.

2. Materials and Methods

2.1. Experimental Sites

The experimental sites are located in the irrigated areas of the Shihezi reclamation area in Xinjiang Province (Figure 1). The climate of the study area is typical arid [26]. The average annual precipitation and potential evaporation are 148 and 1900 mm respectively. The groundwater depth is 2–4.5 m, and groundwater mineralization is generally greater than 10 g L^{-1}. Extreme weather, scarce rainfall and strong evaporation make an efficient water-saving irrigation technique the only way to sustainably develop the oasis.

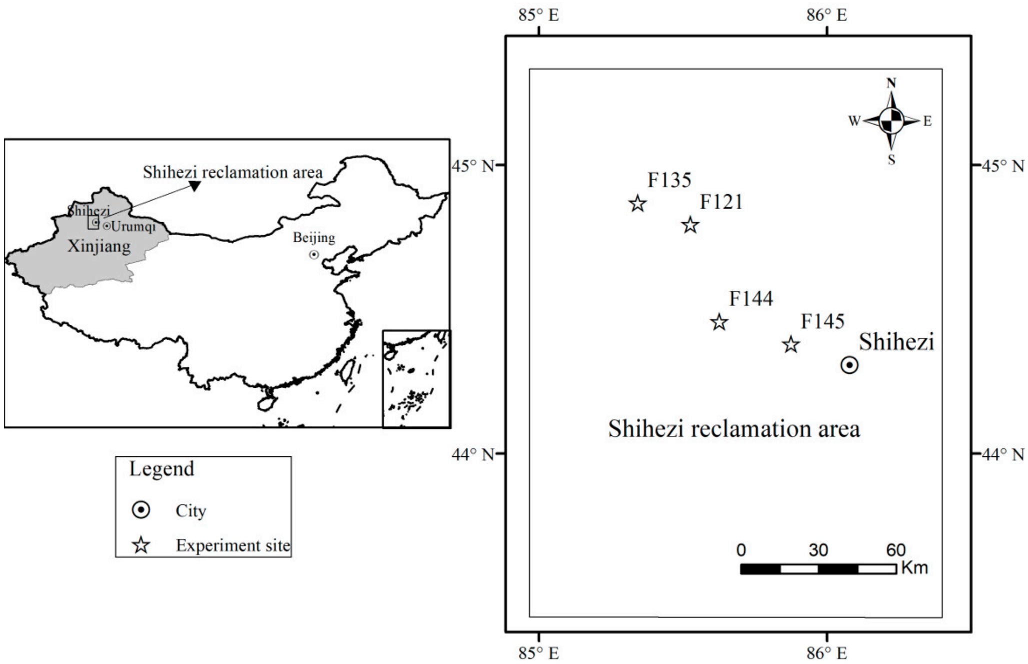

Figure 1. Location map of experimental sites in Shihezi reclamation area, Xinjiang, China.

2.2. Experimental Design and Field Management

The experiment was carried out on four farms, and one newly reclaimed salt wasteland was selected from each of the four farms (the numbers of the farms are F121, F135, F144, and F145; Figure 1) in the experimental area for long-term salt dynamic observation. Each field, with an area of 2000 m^2, was newly reclaimed in 2008 using mulched drip irrigation. In 2016, an experimental field that had been under mulched drip irrigation for 8 years was selected from farm F121 to study the distribution of soil water and salt in the transect perpendicular to the drip pipe. The entire field experiment was conducted from 2008 to 2016. The crops planted were medium long-staple cotton (Xinluzao series); the maximum embedded depth of taproot exceeds 1 m, while most roots are mainly distributed in the 0–60 cm soil layer. According to the climatic characteristics, the cotton was usually sown in the middle of April (dry sowing wet germination) and picked in the middle of September after about 150 days. During the intermission, agricultural operations such as tillage, soil loosening, and pesticide spraying were carried out, and cotton topping was conducted in mid-July. The planting mode adopted the 'one pipe, one film, and four rows' cotton arrangement method. The inner diameter of drip line is 16 mm, the spacing between drip holes is 300 mm, and the designed emitter flow rate is 2.6 L h^{-1}. The width of plastic film was 110 cm, the row spacing of cotton plants was 20 cm, and cotton plants on both sides were 23 cm away from the drip pipe, as shown in Figure 2.

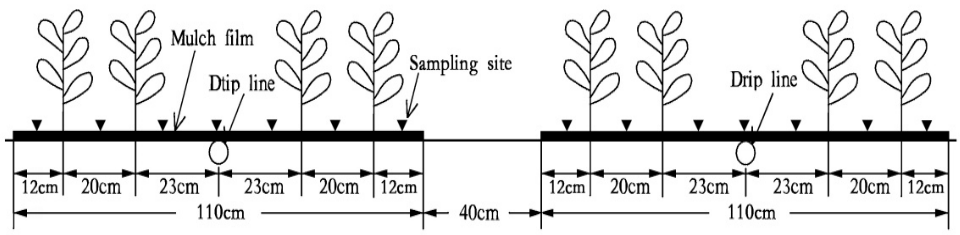

Figure 2. Schematic diagrams of cotton planting, mulching pattern, dripper location, and sampling sites.

Irrigation and fertilization systems were in accordance with local production practices: Irrigating water 8–10 times during the growth period with an irrigation quota of 732–789 mm, and the farmland idle without irrigation treatment during the non-growth period. The water source for irrigation comes from the Manasi River and the salinity of the river water is 0.50~0.97 g L^{-1}. According to the growth of cotton, different fertilizers, mainly urea and potassium ammonium phosphate, were used for each irrigation. The annual amount of fertilizer applied was about 1041 and 708 kg ha^{-1}, respectively. Only shallow tillage and land leveling were applied to the cotton field in the non-growth period.

2.3. Data Collection

For salt wasteland sampling, three sampling areas were selected for each plot using a diagonal sampling method, and soil samples were collected in and out of the mulch film, respectively, in each sampling area. The sampling depths were 0–10, 10–20, 20–30, 30–40, 40–60, and 60–100 cm. From 2011, Soil samples from each layer were analyzed to determine their texture. The sampling was carried out before irrigation in April (pre-sowing), May (seedling stage), June (bud stage), July (blossoming and boll forming stage), August (boll opening stage), and September (harvest period) in 2008–2016.

To study the distribution of soil water and salinity in the transect perpendicular to the drip pipe, sampling work was arranged at seven different sites (Figure 2) along the direction perpendicular to drip irrigation pipe in F121 on 20 June, 23 June, 30 June, and 8 July 2016. In particular, during this period, a single irrigation was carried out on June 21, and the sampling depth of each sampling point were 0–10, 10–20, 20–30, 30–40, 40–60, and 60–100 cm.

Soil water content was determined using an oven-drying method and was given on a mass basis. After measuring the soil water content, soil salinity was measured using weight method [27]. This method is based on water extract from soil sample. The extract is dried to constant weight. We used 15% H_2O_2 to remove the organic matter in the residue. What remained were the total water-soluble salts from the soil. Detailed procedures for soil salinity measurements are presented in the reference. The soil salinity and soil water content in this paper are the average value of multiple samples in each soil layer. The soil salinity is expressed by weight (g kg^{-1}) and the soil water content is expressed in percent of weight (%).

2.4. Statistical Analysis

Soil salinity dynamics and statistical analysis were performed using EXCEL 2010 (Microsoft Corp., Redmond, Washington, DC, USA) and Origin 9.0 (Origin Lab Corp., Northampton, MA, USA). Spatial distribution of soil water and salinity was presented through typical contours using Origin 9.0.

3. Results and Discussion

3.1. Interannual Variation Characteristics of Soil Salinity under Mulched Drip Irrigation during 2008–2016

The changes of soil salinity in the 0–30 and 0–60 cm layers are shown in Figure 3. The soil salinity in the 0–30 cm and 0–60 cm layers is the average value of the corresponding soil layers. As shown in Figure 3a, remarkable decline stage of soil salinity exists in the first few years whether in the 0–30 or 0–60 cm layer with an increase in the years of mulched drip irrigation. The trend lines (Figure 3) indicate that soil salinity decreased sharply from 2008 to 2011, and soil salinity was well correlated with time. Of those, soil salinity in F121 showed the biggest drop. The average soil salinity of F121 in the 0–30 cm layer decreased from 41.8 g kg^{-1} in 2008 to 5.4 g kg^{-1} in 2011, and the average soil salinity in the 0–60 cm layer decreased from 33.7 g kg^{-1} in 2008 to 4.8 g kg^{-1} in 2011. With 2011 as a dividing line of time, the soil decreasing rates in the two periods (before and after 2011) are shown in Table 1. From 2008 to 2011, the 0–30 cm and 0–60 cm soil layers presented a state of desalination with a mean decreasing rate of 6.20 g kg^{-1} per year in 0–30 cm layer and 4.39 g kg^{-1} per year in 0–60 cm layer. While after 2011, soil salinity showed a slight upward trend with a mean decreasing rate of −0.19 g kg^{-1} per year in 0–30 cm layer and −0.3 g kg^{-1} per year in 0–60 cm layer. It is worth noting that the soil salinity of the four fields as a whole shows an obvious downward trend before 2011 or 2012, and a slight upward fluctuation after 2011 or 2012. In other words, the effect of soil desalination is obvious when drip irrigation is applied for 3 years (up to 2011) or 4 years (up to 2012). After that, soil resalinization seems to occur. This result is consistent with previous research results that soil salinity decreases significantly in the initial stage of applying mulched drip irrigation [19].

Table 1. Decrease rate of soil salinity in different soil layers in the salt wastelands, 2008–2016.

Depth (cm)	Time Period	Decrease Rate of Soil Salinity (g kg^{-1} $Year^{-1}$)				Mean (%)
		F121	F135	F144	F145	
0–30	2008–2011	13.44	2.32	2.21	6.81	6.20
	2011–2016	−0.11	−0.21	−0.03	−0.40	−0.19
0–60	2008–2011	10.20	1.42	2.50	3.44	4.39
	2011–2016	−0.14	−0.45	−0.31	−0.49	−0.30

Soil salt seems to re-accumulate after 3–4 years of mulched drip irrigation. The nature of irrigation water may be an influencing factor. Meng et al. [19] pointed out that the amount of salt ions brought into soil through irrigation water (with a salinity of 0.4 g L^{-1}) was 1247 kg ha^{-1} per year, accounting for 5.6% of the initial total soil salt content. Therefore, it could be believed that salt carried by irrigation water is related to soil salt re-accumulation under long-term mulched drip irrigation. In addition, the groundwater in the study area is relatively shallow (2–4.5 m), hence the groundwater brings salt into the soil through evaporation and capillarity under the condition of no drip irrigation and film mulching in the non-growth period, resulting in soil resalinization [22,28]. Moreover, the absence of leaching effects from winter and spring irrigation aggravates this phenomenon [21]. Many studies have shown that soil salinity decreases as the years of mulched drip irrigation increase [3,16,17]. In this study, soil salinity decreases obviously only in the first 3–4 years. Differences in experimental plots, irrigation systems, and field management may be the reasons for the different results. Study also shows that under mulched drip irrigation combined with flood irrigation, soil salt will not accumulate significantly [20]. Therefore, in order to ensure soil health and crop growth, there is an urgent necessity to carry out flood irrigation and salt exclusion measures for salt leaching over a time interval (such as 3–4 years), especially in the non-growth periods.

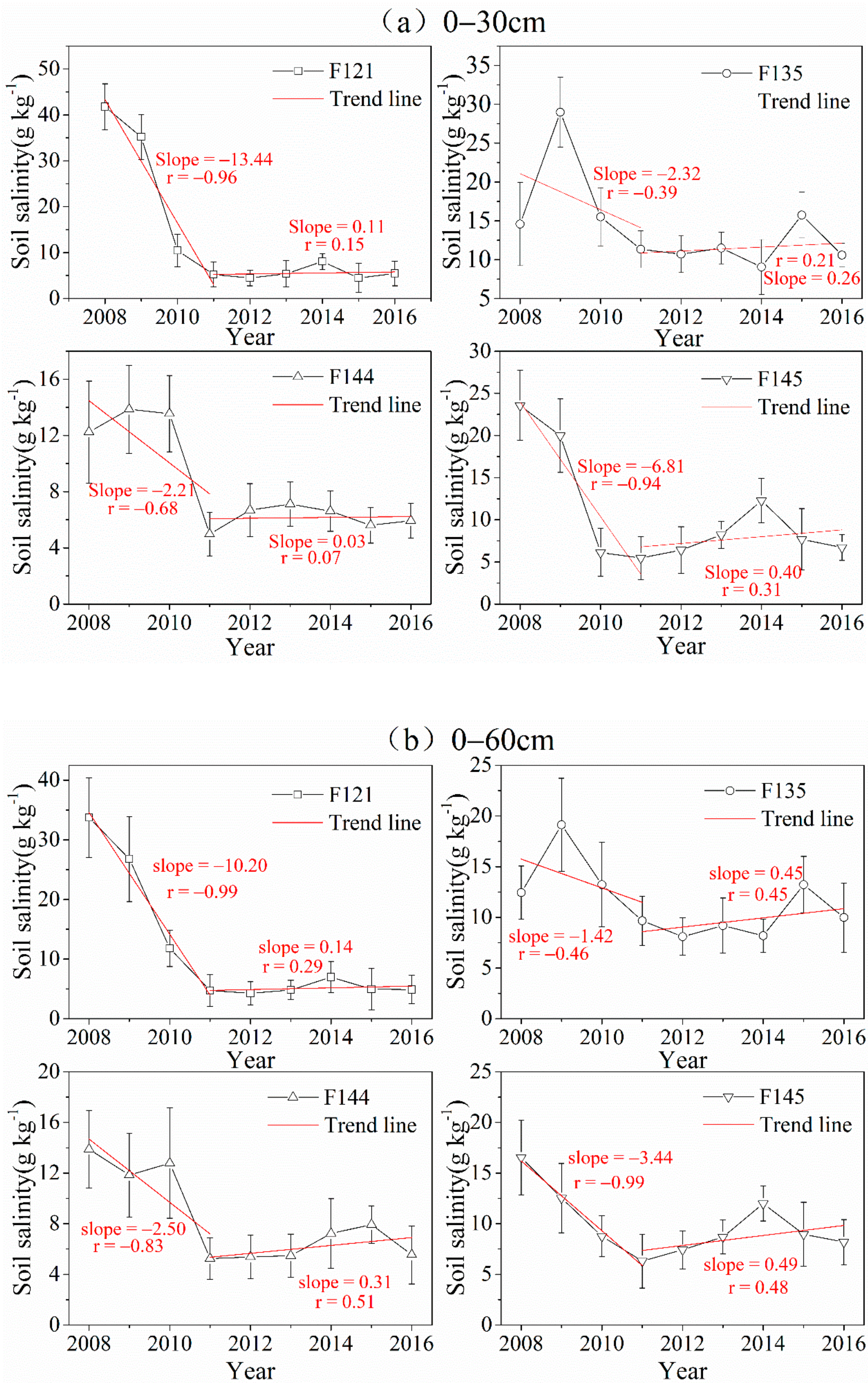

Figure 3. Dynamics of soil salinity in 0–30 cm (**a**) and 0–60 cm (**b**) layers.

3.2. Variation Characteristics of Soil Salinity during Growth Period under Mulched Drip Irrigation

The changes of soil salinity in the 0–60 cm soil layer during the cotton growing periods from 2008 to 2016 are shown in Figure 4. Soil salinity is at a high level at pre-sowing each year. With the beginning of drip irrigation, soil salinity decreases obviously and then fluctuates. During the harvest period in September, soil salinity tends to rise again. This phenomenon has a lot to do with farmland management in the non-growth period. Without irrigation and mulching in the non-growth period, soil salt cannot be leached. During the non-growth period, the groundwater level gradually restores and reaches its peak in the following spring [22], and the salt in groundwater reaches the upper soil layer through evaporation and capillarity [29]. Immediately after irrigation, soil salt is transported to the deep layer due to leaching of irrigation water. During the harvest period in September, soil salt cannot be leached with the cessation of irrigation, and the salt in the deep layer begins to move upward [30]. Therefore, the control of groundwater level and leaching of soil salt through flood irrigation in the non-growth period seem to be important measures to regulate irrigation-induced soil salinity and provide a healthy soil environment for cotton growth in growth period.

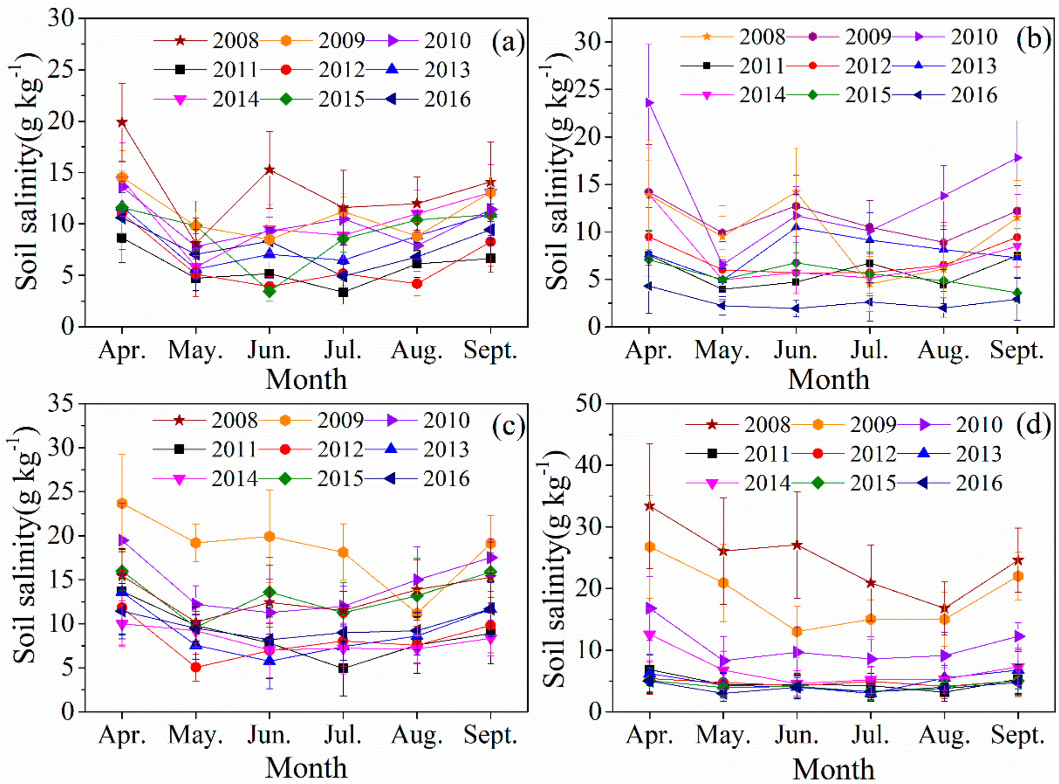

Figure 4. Changes of soil salinity in the 0–60 cm soil layer during the growth period in (**a**) F121, (**b**) F135, (**c**) F144, and (**d**) F145.

3.3. Soil Salinity Distribution along the Vertical Direction in Different Years

The distribution of soil salinity at different depths in 2011–2016 is shown in Figure 5, which also shows the soil texture of each layer. As depicted in Figure 5, the soil salinity of F121 basically decreases with depth in all years except for the relatively high soil salinity in the 60–100 cm layers. According to the soil texture of different soil layers in F121, the soil texture is loam above 30 cm and sandy soil below 30 cm. Compared with loam, sandy soil, with a larger particle size, has stronger permeability, which is more conducive to the movement and diffusion of soil water and salt with the infiltration of irrigation water [31]. Therefore, the soil salinity in the upper loam is higher than that in the bottom sandy soil. Similarly, since the layered soil texture of F135 is very similar to that of F121, the soil salinity of F135 also decreases with an increase of depth. In contrary, the soil salinity of F144 increases with depth as a whole due to the soil texture is loam in the upper part and heavy loam in the bottom part. Notably, the soil salinity of F144 accumulates in the soil layer transiting from loam to heavy loam. Also, the soil texture of F145 is loam in the upper part and clay in the lower part, and the soil salt accumulates in the soil layer transiting from loam to clay. Based on the soil texture, there is a common feature of soil salinity distribution in the vertical direction, that is, soil salt accumulates near the soil layer transiting from coarse soil to fine soil.

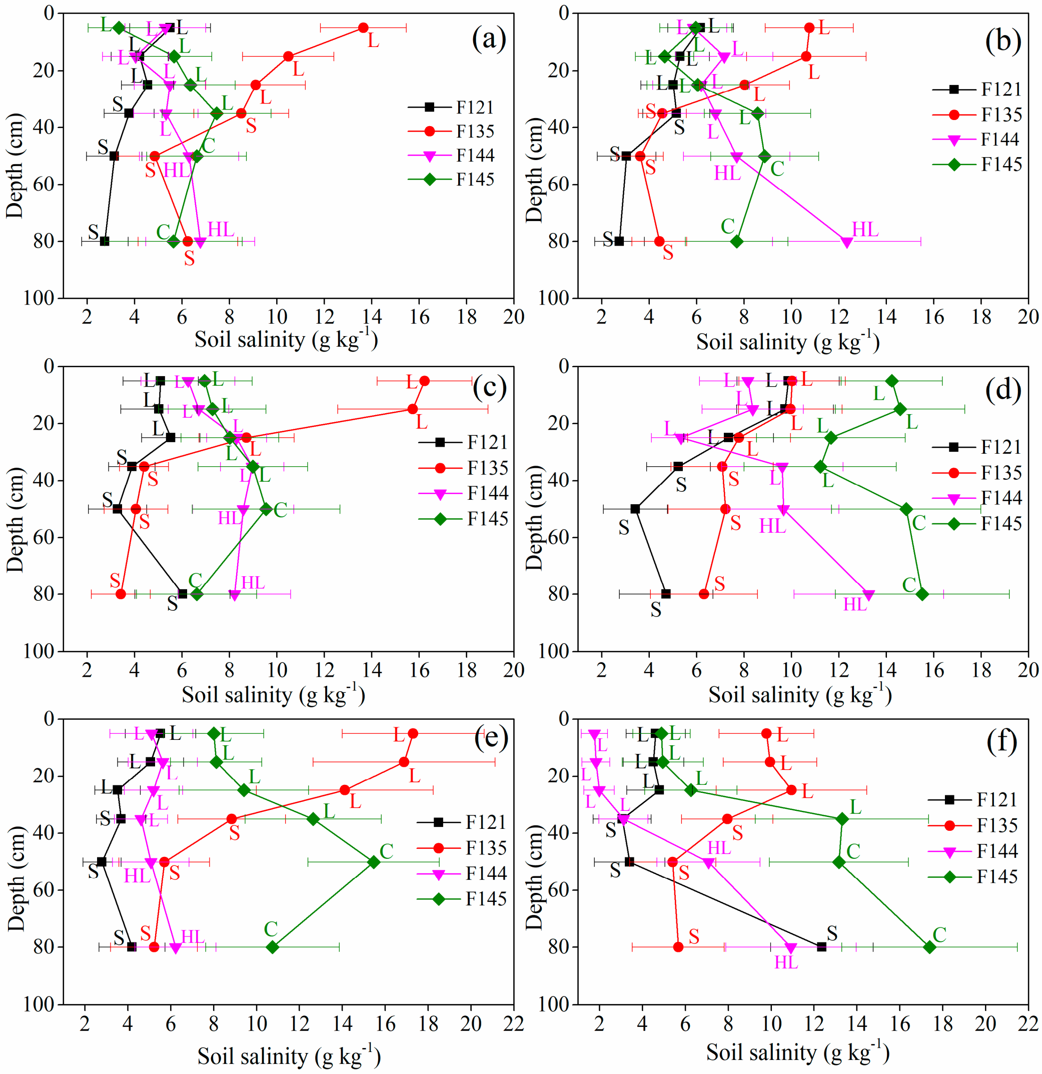

Figure 5. Distribution of soil salinity and soil texture at different soil depths in salt wastelands under mulched drip irrigation, 2011–2016 ((**a**)–(**f**): 2011–2016, S: sand, L: loam, HL: heavy loam, C: clay).

The permeability of the fine soil particle layer is poor, restricting the infiltration of irrigation water. Moreover, the fine-grained soil layer prevents the salt in the groundwater from migrating to the shallow coarse soil layer, thus alleviating the salinization of shallow soil caused by groundwater evaporation, especially in the region with shallow groundwater level [25,32]. In addition, compared with phreatic evaporation, downward infiltration of irrigation water is dominant under mulched drip irrigation. Therefore, soil salt will accumulate near the fine soil layer due to the relatively higher permeability of coarse soil than fine soil. However, for the soil layer with fine particles in the upper part and coarse particles in the bottom part, the leaching effect of irrigation water in the upper soil layer is poor, so soil salt will accumulate in the upper part, while the soil permeability in the bottom part is good, and it is easy for soil salt to be leached to the deep layer. Generally, the poor soil water and salt movement caused by uneven vertical distribution of soil texture leads to soil salt accumulation. Zhang et al. also found that soil salt would accumulate above the relatively impermeable layer [25]. Therefore, soil texture has a great influence on the distribution of soil salinity. Deep tillage can improve water infiltration, facilitate soil water storage and water retention [33–35], reduce soil bulk density and promote salt migration to deep layer, especially for continuous cropping farmlands [35]. Therefore, deep tillage of the farmland should be adopted regularly to alleviate salt accumulation in the root zone.

3.4. Effects of Soil Water Distribution on Soil Salt Distribution before and after a Single Irrigation

3.4.1. Soil Water Distribution in the Soil Profile Perpendicular to the Drip Line

The distribution of soil moisture in the vertical profile is shown in Figure 6. Before irrigation, in the horizontal direction, the soil water content near the dripper is the lowest, and slightly increases in the direction away from the dripper. The reason may be that soil water move to cotton roots under the action of root water uptake. In the vertical direction, the soil water content below the dripper is lower than that at other locations within the 0–30 cm layer. The soil water content in the layer below 30 cm is markedly increased, all more than 20%. In the 30–60 cm layer under the cotton plants, there are wet bulbs with high soil water content (Figure 6a). The reason might be that the cotton roots absorb water from the surrounding zone.

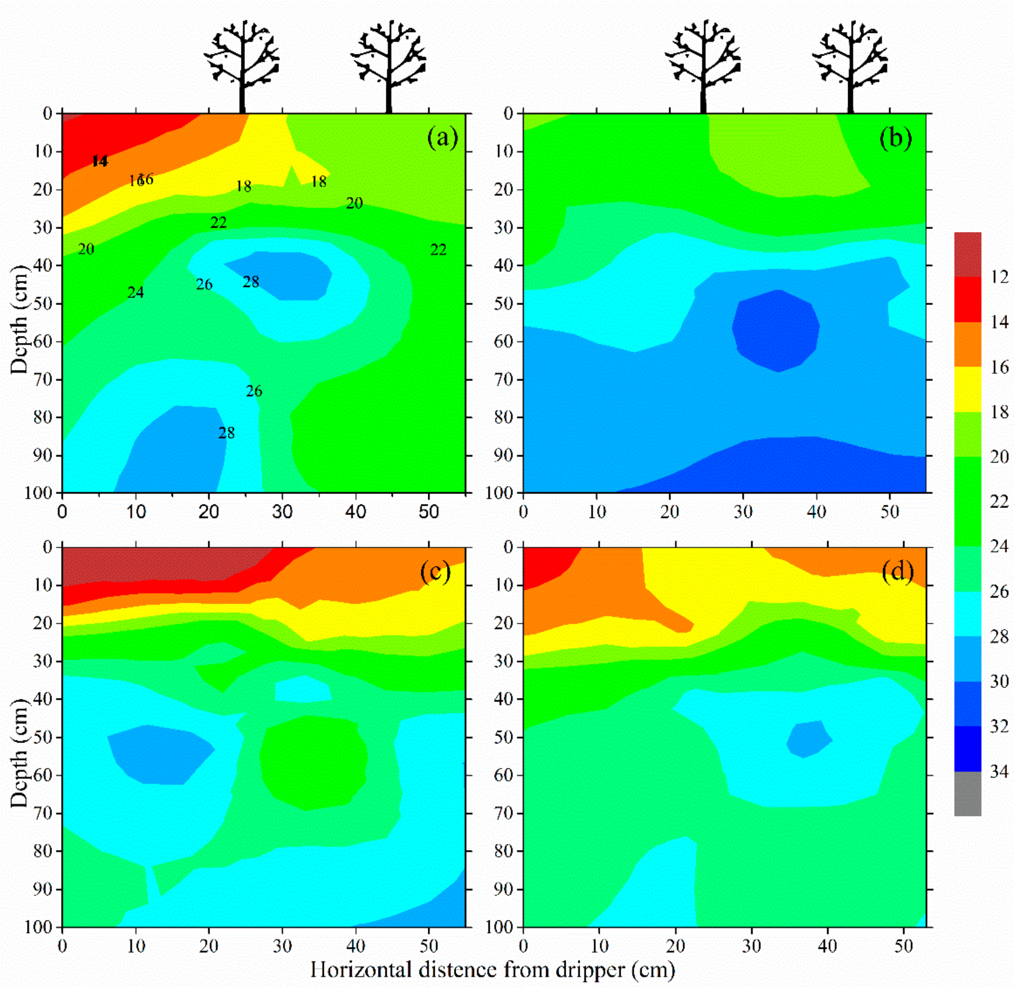

Figure 6. Vertical distribution of soil water content (%, by mass) under mulched drip irrigation on (**a**) 20 June, (**b**) 23 June, (**c**) 30 June, (**d**) 8 July 2016.

Following a single irrigation, the soil water content increases appreciably and presents a nearly stratified distribution after a period of infiltration (Figure 6b). The slight fluctuation in the same layer might be related to the cotton root and soil microstructure, which affects soil permeability [36]. Similarly, there are wet bulbs with high soil water content in the soil layer (40–70 cm) where the roots of cotton plants are relatively concentrated. A few days after irrigation (Figure 6c), the soil water content in each layer decreases, among which the soil water content of the top 40 cm layer decreases obviously; in the shallow soil layer, the farther away from the dripper, the higher the soil water content. Notably, in the 40–70 cm layer under cotton plants, the soil water content is lower than that in the surrounding zone. The decrease of soil water content in shallow soil is related to the continuous downward infiltration of irrigation water, while the decrease of soil water at 40–70 cm depth under cotton plants may due to absorption of water in the process of root growth.

Until the next irrigation (Figure 6d), the soil water in the shallow soil layer increases slightly, while there are obvious wet bulbs at the depth of 40–70 cm under the cotton plants. This phenomenon indicates that the water infiltration driven by drip irrigation is very weak. However, cotton is at the flowering and boll setting stages, during which water consumption is the greatest [37]. Therefore, in the absence of continuous irrigation water, cotton roots not only absorb water from the surrounding zones, but also consume the soil moisture generated from phreatic evaporation under intense evapotranspiration to meet the needs of cotton growth.

In general, before and after an irrigation activity, the soil water content near the dripper first increases and then decreases. This should be due to the constant infiltration of irrigation water. However, the change of soil water content in the root zone is more complex. The distribution of soil water is closely related to crop roots [38]. After irrigation, the well-developed cotton root system in the root zone will absorb water quickly, and the surrounding water moves towards the root system under the action of water potential gradient to supply sufficient water for the root system and make it develop better. Therefore, soil water content in the root zone will increase following irrigation. After a period of infiltration, the zones with developed root system in turn have a stronger ability to absorb water, so that the soil water content in the root zone was relatively lower than that in surrounding zones (Figure 6c). When irrigation stopped, the infiltration of irrigation water is gradually replaced by the upward migration of groundwater caused by phreatic evaporation, crop evapotranspiration and capillarity. The upward gaseous water condenses and accumulates in shallow soil, resulting in a slight increase in soil water content in the shallow layer. The wet bulbs in the root zone (Figure 6d) are due to the cotton root water uptake, especially in periods of high water-consumption. Moreover, there are great differences in root system distribution in the different growth stages of cotton [39]. These differences will result in differences in root water uptake [38], leading to differences in soil water content distribution with horizontal location and soil depth [40].

3.4.2. Soil Salinity Distribution in the Soil Profile Perpendicular to the Drip Line

Distribution of soil salinity in soil profile perpendicular to the drip line before and after one drip irrigation is shown in Figure 7. Before irrigation (Figure 7a), the closer to the dripper, the lower the soil salinity is in the shallow soil layer. The high salinity zone is mainly concentrated in 50–70 cm soil layer under the cotton plants. Following drip irrigation (Figure 7b), the desalinization zones in the soil layer above 70 cm obviously enlarge, and approximately show quarter annuluses distribution with the dripper as the center. While the high salinity zones move down, and the salt accumulates in the soil layer below 70 cm under the cotton plants. From Figure 7c, it can be seen that the soil salinity decreases in the 0–20 cm layer under the dripper but increases slightly in the 30–70 cm layer. While under the cotton plants, soil salinity increases slightly in the 20–60 cm layer and greatly in the soil layer below 60cm. This might be due to that the weakening of irrigation water's downward infiltration enhances the upward movement of soil water in the deep layer under the strong effect of evapotranspiration. Therefore, soil salts move upward with the water mobilization. Comparatively, soil salinity in the 0–20 cm soil layer changes little in the whole soil profile on July 8 (Figure 7d), while soil salinity increases greatly in layers below 20 cm under the cotton plants. Likewise, the upward movement of salt with groundwater caused by the lack of irrigation water infiltration and crop evapotranspiration might be the main reason.

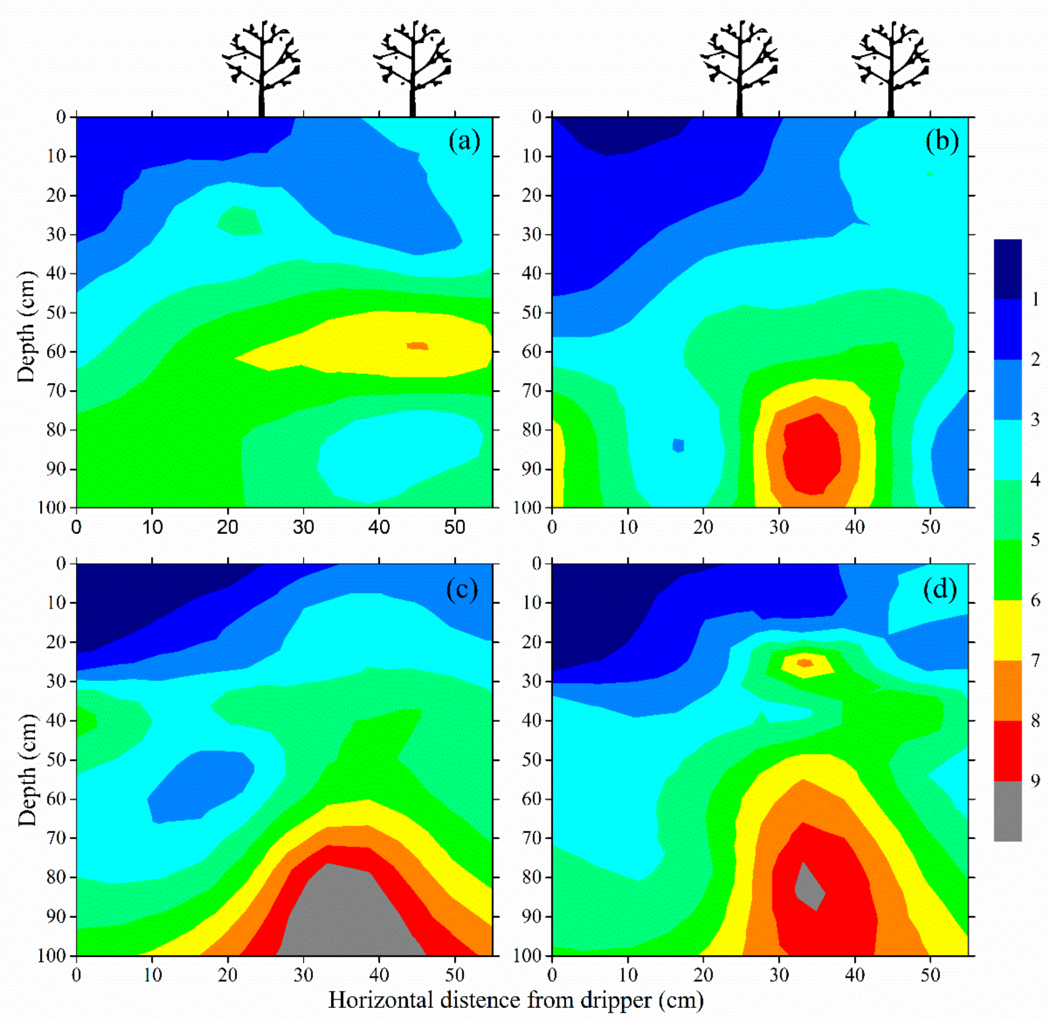

Figure 7. Vertical distribution of soil salinity (g kg^{-1}) under mulched drip irrigation on (**a**) 20 June, (**b**) 23 June, (**c**) 30 June, (**d**) 8 July 2016.

To sum up, after a single irrigation, soil salinity in the soil layer above 70 cm decreases, and soil salt accumulates in the soil layer below 70 cm under the cotton plants. Several days after irrigation, the soil salinity in the shallow layer do not change dramatically, while under the cotton plant, soil salinity shows a rising trend in the soil layer below 30 cm. There is a close relationship between soil water distribution and salt distribution under mulched drip irrigation [41]. Therefore, the distribution and change of soil salinity should be analyzed from the perspective of soil water. In the initial stage after irrigation, the infiltration of soil water from top to bottom takes a dominant position, and soil salt moves down with soil water, resulting in the decrease of soil salinity in the shallow layer and the accumulation of soil salt in the deep soil layer, especially under cotton plants [42]. After a period of time, the cessation of irrigation leads to the weakening of water infiltration, while upward groundwater migration is dominant due to phreatic evaporation, capillarity and crop transpiration [43,44]. As a result, the salt in the groundwater gradually moves upward and accumulates as shown in Figure 7. These changes in soil salinity after irrigation are consistent with the study of Qi et al., which showed that the soil salt tended to move upward from deeper layer to top layer as time passed after irrigation [41]. Soil salinity shows an upward trend before the next irrigation. Therefore, the irrigation interval should be shortened, and the irrigation frequency should be appropriately increased to leach and restrain soil salt. Irrigation is leaching process for soil salt, and a suitable irrigation schedule is of great significance for soil desalination under mulched drip irrigation.

4. Conclusions

In this study, the soil salinity of newly reclaimed salt wasteland was monitored from 2008–2016 based on field experiments. Besides that, the distribution of soil salinity and water in the transect perpendicular to the drip pipe before and after a single drip irrigation was also investigated from 20 June 2016 to 8 July 2016. From the results obtained in this work, the following can be concluded that:

Under long-term mulched drip irrigation, the soil salinity in 0–30 cm and 0–60 cm layers showed a sharp decline in the first 3 to 4 years and then began to fluctuate and showed an upward trend. During the growth period, soil salinity was generally higher at pre-sowing and late harvest period, and decreased immediately after drip irrigation. Soil texture and soil water seriously affect the dynamics and distribution of soil salinity. Soil salt will accumulate in the soil layer transiting from coarse to fine soil from top to bottom. After a single irrigation, soil salt will migrate first downward and then upward with the change of soil water. Therefore, corresponding measures such as flood irrigation, deep tillage, optimization of irrigation regime, and salt exclusion hydraulic measures should be applied to alleviate soil resalination and promote the development of agriculture under long-term mulched drip irrigation. The quantitative study on the effects of these measures on soil desalination under long-term mulched drip irrigation will be the topics in our future research.

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