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Effect of Ridges and Furrows Plant of Wolfberry on Alkalized Solonchak

Wang Xu [1], **Sun Zhaojun** [1,2,3,4*], **Sameh El-Sway** [4,5], **Wang Fang** [2]

[1] School of Civil Engineering and Hydraulic Engineering, Ningxia University, Yinchuan 750021, CHINA

[2] School of Resources and Environmental Science, Ningxia University, Yinchuan 750021, CHINA

[3] Ningxia (China-Arab) Key Laboratory of Resources Assessment and Environmental Regulation in Arid Regions, Yinchuan 750021, CHINA

[4] Institute of Environmental Engineering, Ningxia University, Yinchuan 750021, CHINA

[5] Vegetable Research Department, Agricultural and Biological Division, National Research Centre, Dokki, Giza 12311, EGYPT

[*] Corresponding author: sunzhaojunyx@126.com

Abstract

Aiming at the bottleneck problems of high salinity of surface soil, poor physical and chemical properties of soil and difficult growth of plants in alkalized solonchak of Jingyuan, Gansu Province, field experiments were carried out on the basis of uniform application of desulfurized gypsum 22 t/hm^2. Three irrigation quotas: 8,625m^3/hm^2, 9,375m^3/hm^2 and 10,125 m^3/hm^2, were set up under the two planting modes of ridge and furrow planting and non-ridge planting, and effects of two planting methods and irrigation quota on soil pH, degree of alkalisation, total salt content and wolfberry growth were studied. The results showed that: (1) The pH value, degree of alkalisation and total salt content of the soil were significantly reduced by all treatments, and the irrigation water and rainfall could be collected in the furrows, so as to increase the soil water content. The soil salinity of ridging treatment was 14.2% lower than that of non-ridge treatment in 0~40 cm soil layer, and the growth index of wolfberry was higher than that of non-ridge treatment. Under the two planting methods, the desalting effect increased with the increase of the irrigation volume. The survival rate, plant height, crown width and yield indexes of wolfberry increased with the increase of irrigation amount. There was no significant difference in growth indexes of wolfberry when the irrigation quotas were 9,375 m^3/hm^2 and 10,125 m^3/hm^2. Considering that the study area is located in arid area and water resources are limited, excessive irrigation will not only waste water resources but also increase the risk of secondary salinization, therefore, ridge and furrow planting is suitable for wolfberry planting in alkalized solonchak of Baiyin, Gansu, and the appropriate irrigation quota is 9,375 m^3/hm^2.

Keywords: irrigation, ridge, planting pattern, alkalized solonchak, soil salinity

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INTRODUCTION

Soil salinization is one of the main factors restricting agricultural production and ecological environment in China and has become a global problem (Kim et al. 2017). According to the survey, the existing saline and alkaline land in Gansu is nearly 1.04×10^6 hm^2, accounting for 19.22% of cultivated land in Gansu (Yang and Wang 2015). There are large areas of saline alkali wasteland in Jingyuan County, Baiyin, Gansu, and the soil physical and chemical properties are poor, which restricts the sustainable development of local agriculture. However, the area is flat, adjacent to the Yellow River, and has great development potential. Lycium barbarum is a deciduous shrub of Solanaceae. It has high medicinal value and broad market prospects, with a good resistance to drought and saline-alkali, which has been widely planted in arid areas (Zhou et al. 2017). Its branches and leaves are flourishing and its roots are well developed. Its root has the rhizobium bacteria, which has the nitrogen fixation function. Perennial plants can prevent wind and fix sand, reduce wind speed, increase atmospheric humidity, and regulate the climate of field plots (Drake et al. 2016, Muharini et al. 2017). The local area is dry with little rain, and the evaporation is strong. After the traditional flat planting of wolfberry, the irrigation is limited, and the poor secondary salinization effect is not conducive

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Table 1. Main physical and chemical property of tested soils

Soil depth/cm	Ion ingredients / (cmol·kg^{-1})								pH value	Salinity /(g·kg^{-1})	Alkalinity /%	Bulk density / (g cm^{-3})
	Na^{+}	Ca^{2+}	K^{+}	Mg^{2+}	CO2- 3	HCO- 3	Cl^{-}	SO2- 4				
0-20	9.25	0.28	0.27	0.48	0.95	1.85	2.25	1.08	9.05	8.35	29.35	1.32
20-40	8.32	0.31	0.29	0.55	0.72	1.57	2.37	1.13	8.72	7.17	23.54	1.47
40-60	7.56	0.32	0.32	0.57	0.63	1.41	2.40	1.26	8.54	6.42	21.25	1.56

to the growth and development of wolfberry, resulting in smaller crown width and frequent salt return phenomenon (Wozniak et al. 2012). How to improve the water and salt environment of saline-alkali soil by cultivation measures and ensure the sustainability of the improvement effect is a problem that needs to be solved for local planting of wolfberry. Ridge and furrow planting refers to the alternating arrangement of ridges and furrows and the planting of crops in the ridges and furrows. The ridge and furrow system consisting of ridges and gullies has the function of collecting rain and storing water (Zhanget al. 2013a). Some studies have showed that the ridging changes the surface, intercepts part of the runoff, collects rainfall, and increases soil water storage for downward movement (Zhang et al. 2013b, Zhao et al. 2014). The water in furrow is superposed, which promotes the growth and development of crops, and improves the crop yield and water use efficiency. In order to alleviate the effect of salt-alkali stress on crops, irrigation process is indispensable. Dissolving soluble salt by irrigation water and leaching can effectively reduce the salt content of crop root soil (Dai et al. 2015). Some studies have shown that the amount of irrigation has a direct impact on the leaching effect of soil salinity (Alarcón and Juana 2016). If the amount of irrigation is large, it will waste water resources, and may cause deep leakage, and raise the groundwater level, resulting in secondary salinization of the soil. If the amount of irrigation is small, the salt can't be fully leached, the effect of salt leaching is poor, and the phenomenon of salt return is easy to occur.

For ridges and furrows planting in the saline-alkali land, using the role of rainwater collection and water storage in ridge furrow to increase soil water content to achieve secondary salinization and guarantee the improvement effect is one of the effective ways to break the low survival rate of local wolfberry. At present, there is still insufficient research on the change of water and salt in saline-alkali soil caused by planting wolfberry in ridges and furrows, and it is still unclear how ridges and furrows affect the water and salt environment of saline-alkali soil and how to create suitable growth environment for plants. Therefore, field positioning experiments were conducted in Jingyuan County, Baiyin City, Gansu Province, to study the effects of ridge and furrow planting, non-ridge planting and different irrigation quotas on pH value of alkali saline soil, alkalinity degree, total salt content and growth of wolfberry on the basis of unified application of desulphurization gypsum, in order to find out the influence of planting mode and irrigation quota on saline-alkali soil, and provide theoretical basis and technical support for the optimization of saline-alkali soil improvement technology and field soil water and salt regulation and management.

MATERIALS AND METHODS

Site Characterization

The experiment was carried out in Wuhe Township, Jingyuan County, Baiyin, Gansu Province (36°44' N, 104°58' E). The area belongs to temperate continental climate with high summer temperature, sparse rainfall and uneven annual distribution. The annual average temperature is 10.3 ºC the annual average precipitation and evaporation are 235 mm and 1,672 mm, respectively. The temperature is the lowest in January and the highest in July. The soil clay particles (<0.002 mm) in 0~60 cm soil layer account for 14.7%, silt particles (0.002~0.02 mm) account for 39.5%, sand particles (0.02~2.0 mm) account for 45.8%, and the soil texture is clay loam (Wang and Zhu 1992). The organic matter content of 0-60 cm soil layer is 0.63～0.82 %, alkali-hydrolysable nitrogen is 17.82～28.35 mg/kg, the rapid available phosphorus is 3.85～5.17 mg/kg, the rapidly available potassium is 185.63～225.35 mg/kg, and other physical and chemical properties are shown in **Table 1**. From **Table 1**, it can be known that the total salt content of soil is above 6.4 g/kg, and the total salt content decreases with the increase of soil depth, the degree of alkalinity is above 21%, the PH value is above 8.5, and in 0-60 cm soil layer, cations are mainly Na^+ and anions are mainly Cl^-.

Experimental Design

On the basis of unified application of desulphurization gypsum 22 t/hm^2 and leaching requirement of 7,500 m^3/hm^2 (Sun 2017), referring to local conventional irrigation quota 1,950 m^3/hm^2 for wolfberry, six treatments of non-ridge planting+irrigation quota 8,625 m^3/hm^2 (T1), non-ridge planting+irrigation quota 9,375 m^3/hm^2 (T2), non-ridge planting+irrigation quota 10,125 m^3/hm^2 (T3), ridging planting+irrigation quota 8,625 m^3/hm^2 (T4), ridging planting+irrigation quota 9,375 m^3/hm^2 (T5), and ridging planting+irrigation quota 10,125 m^3/hm^2 (T6) were set and each treatment was repeated 3 times.

In non-ridge test plot, 40 m^3/hm^2 farm manure and 22 t/hm^2 desulfurized gypsum were spread on the surface, which was mixed with the surface soil by rotary tillage. In the experimental plot of ridging, the ridging machinery was used for ridging, the ridge height was 0.3 m, the ridge width was 0.4 m, the furrow width was 0.4 m, the interval of each furrow was 0.8 m, and 40 m^3/hm^2 farm manure and 22 t/hm^2 desulfurized gypsum were spread on the surface, which was mixed with the surface soil by rotary tillage. Soil salt content in the experimental area was high, so irrigation was needed to leach salt to grow wolfberry. According to the principle that "small amount of water can dissolve salt, and large amount of water can leach salt", the salt was leached three times continuously (Yang et al. 2015). After leaching, tree pits were dug in the furrow according to the specification of 0.5 m plant spacing (pit depth was 0.3 m and diameter was 0.2 m), and tree pits were dug according to the specification of 0.5×0.8 m plant spacing for the non-ridge treatment. The specifications of tree pits were the same as those in the ridging treatment plot. Wolfberry was planted on April 28, 2016. A wolfberry seedling was planted in each tree pit. The seedlings were planted into earth, filling and treading the soil. The row spacing between ridging and non-ridge treatment wolfberry was 0.5×0.8 m. After planting, irrigation should be conducted according to the amount of irrigation designed by the experiment. After surface drying, the compaction was broken in time.

The winter irrigation quota for all treatments was 1,650 m^3/hm^2. Besides water irrigation, the wolfberry was irrigated 5 times in the whole growth period (Zhang et al. 2014). Irrigation was conducted in the middle of 5-9 months of each year. The irrigation quota of T1 and T4 treatments was 1,725 m^3/hm^2, the irrigation quota of T2 and T5 treatments was 1,875 m^3/hm^2, and the irrigation quota of T3 and T6 treatments was 2,025 m^3/hm^2.

Experimental Methods

The test began in May, 2016. The samples were collected after irrigation 7 days. Soil samples were collected in each experimental plot with "S" shape. The non-ridge treatment was based on the ground surface, and the ridging treatment was based on the bottom of the ridge and furrow. Soil samples were taken from 0~20, 20~40 and 40~60 cm soil layers at 5 cm from the trees in each experimental plot. 3 soil samples were collected in each plot, and debris was removed from the soil sample. The soil samples were dried, ground and screened with a 1 mm aperture. The cutting ring method was adopted for volume weight, and the drying method was adopted for moisture content. After mixing m (soil): V (water) = 1:5 with deionized water, it was fully shook and filtered, and the supernatant was taken. The pH value was measured by Mettler Toledo S220 multi parameter tester, soil total salt content was determined by conductance method, the cation exchange capacity was determined by ammonium chloride-ammonium acetate exchange method, the exchangeable Na^+ was determined by ammonium acetate-ammonium hydroxide-flame photometry, the degree of alkalization was calculated by the percentage of exchange capacity of exchangeable Na^+ and exchangeable cation, the contents of K^+ and Na^+ were determined by minusing, Ca^{2+} and Mg^{2+} were determined by EDTA titration method, Cl^- was determined by $AgNO_3$ titration method, SO2- 4 was determined by back titration, and CO2- 3 and HCO- 3were determined by double indicator titration. The specific content refers to the literature (Bigham 1965).

The irrigation amount was determined by water meter, the survival rate was calculated by the percentage of the number of surviving seedlings and the total number of seedlings in the experimental plot, the preservation rate was calculated by the percentage of the number of surviving seedlings in the second year and the total number of seedlings, and the crown width and the height of seedlings were measured by tape measure. After the wolfberry was ripe, the fruit was picked on July 4, 2016, and then was picked every 5 days. At the end of August, the fruit was picked every 7 to 10 days. After each picking, the fruit was dried at 45 °C in drying oven. Finally, the yield of wolfberry dried fruit in each experimental plot was calculated.

Data Processing

SPSS19.0 software was used for significance test, variance analysis and regression analysis, and Surfer 10.0 software was used for contour map.

RESULTS

Bulk density, pH and Alkalinity

The bulk density, pH value and alkalinity degree of soil treated by T1~T6 for 2 years were all lower than

Table 2. Effect of different treatments on bulk density, pH value and alkalinity of soil

Year	Treatment	Bulk density / (g/cm^3)	pH value	Alkalinity / (%)
2016	T1	1.40±0.02a	8.32±0.09a	17.99±0.26a
	T2	1.38±0.03a	8.22±0.08a	17.82±0.22a
	T3	1.35±0.02a	8.17±0.07a	17.65±0.26a
	T4	1.38±0.02a	8.16±0.07a	17.73±0.17a
	T5	1.33±0.03a	8.05±0.08ab	17.55±0.30ab
	T6	1.29±0.03a	7.95±0.08b	17.37±0.29b
2017	T1	1.28±0.03a	8.09±0.08a	15.82±0.44a
	T2	1.25±0.02a	7.96±0.09a	15.57±0.41a
	T3	1.18±0.03b	7.92±0.07a	15.32±0.25a
	T4	1.26±0.02a	8.02±0.07a	15.65±0.43a
	T5	1.19±0.04ab	7.85±0.04a	15.16±0.36a
	T6	1.15±0.02b	7.73±0.05b	14.87±0.22b

those of native soil (**Table 2**). The soil bulk density, pH value and alkalinity degree decreased with the increase of irrigation quota under ridge and furrow planting or non-ridge planting. Under the same irrigation quota, the soil bulk density, pH value and alkalinity degree under ridging planting were lower than those under non-ridge planting. In the first year, the soil bulk density, pH value and alkalinity degree of ridging treatment were 3.1%, 2.2% and 1.5% lower than that of non-ridge treatment, respectively, among which, the soil bulk density, pH value and alkalinity degree of T6 treatment were the lowest, 12.2%, 10.7% and 34.8% lower than that of the original soil, respectively. The soil bulk density of ridging treatment was not significantly different from that of non-ridge treatment ($P>0.05$). In the second year, the soil bulk density, pH value and alkalinity degree of each treatment decreased further on the basis of the first year, and the soil bulk density, pH value and alkalinity degree of the ridging treatment decreased by 3.0%, 1.3% and 3.4% respectively compared with the non-ridge treatment. The bulk density, pH value and alkalinity degree of T6 treatment were the lowest, and the pH value and alkalinity degree index of T6 treatment were significantly different from those of other treatments ($P < 0.05$).

Soil Moisture

Soil profile moisture is mainly affected by irrigation, climate and plant uptake. Taking the soil profile moisture variation in 2017 as an example, the effects of different treatments on soil profile moisture are analyzed (**Fig. 1**). The experimental results showed that before June, the soil water content in 0~20 cm soil layer increased with the increase of irrigation quota. During the growth and development period of wolfberry, the water required for plant growth increased, and the water content of surface soil decreased gradually due to the influence of surface evaporation and water absorption of root system. As shown in **Fig. 2**, the soil water content in 0~60 cm soil layer increases with the increase of soil depth. The soil moisture content in 0~20 cm layer decreases firstly and then increases with the increase of time. The surface soil moisture content is the lowest in July and August, which is due to the intense evaporation in summer. In September, the temperature decreases slightly, so the surface soil moisture content increases slightly. The soil moisture content of ridging treatment in 0~20 cm soil layer is higher than that of non-ridge treatment. After irrigation, the water accumulates in the ridge and furrow, which increases the surface soil moisture content in the ridge and furrow.

Soil Salinity

Soil salinity is mainly affected by soil water movement. Taking the variation of total salt content in soil profile in 2017 as an example, the effects of different treatments on total salt content in soil profile are analyzed (**Fig. 2**). The soil total salt content of each treatment in 0~20 cm soil layer decreased with the increase of irrigation, and the soil total salt content of each treatment increased with the increase of soil depth. Since July, the temperature rise and evaporation was strong in summer, which leaded to salt migration to the surface soil, and salt returned to the surface soil in all treatments. The salt returning strength of ridging treatment was lower than that without ridging. Under the same irrigation quota, the soil salinity of ridging treatment was lower than that of non-ridge treatment. The soil salinity of ridging treatment in 0~40 cm soil layer was 14.2% lower than that of non-ridge treatment on average, and ridging helped to reduce soil salinity. Ridge and furrow planting was helpful to store precipitation and irrigation water in the furrow, and the effect of secondary salinization was better than that of non-ridge planting.

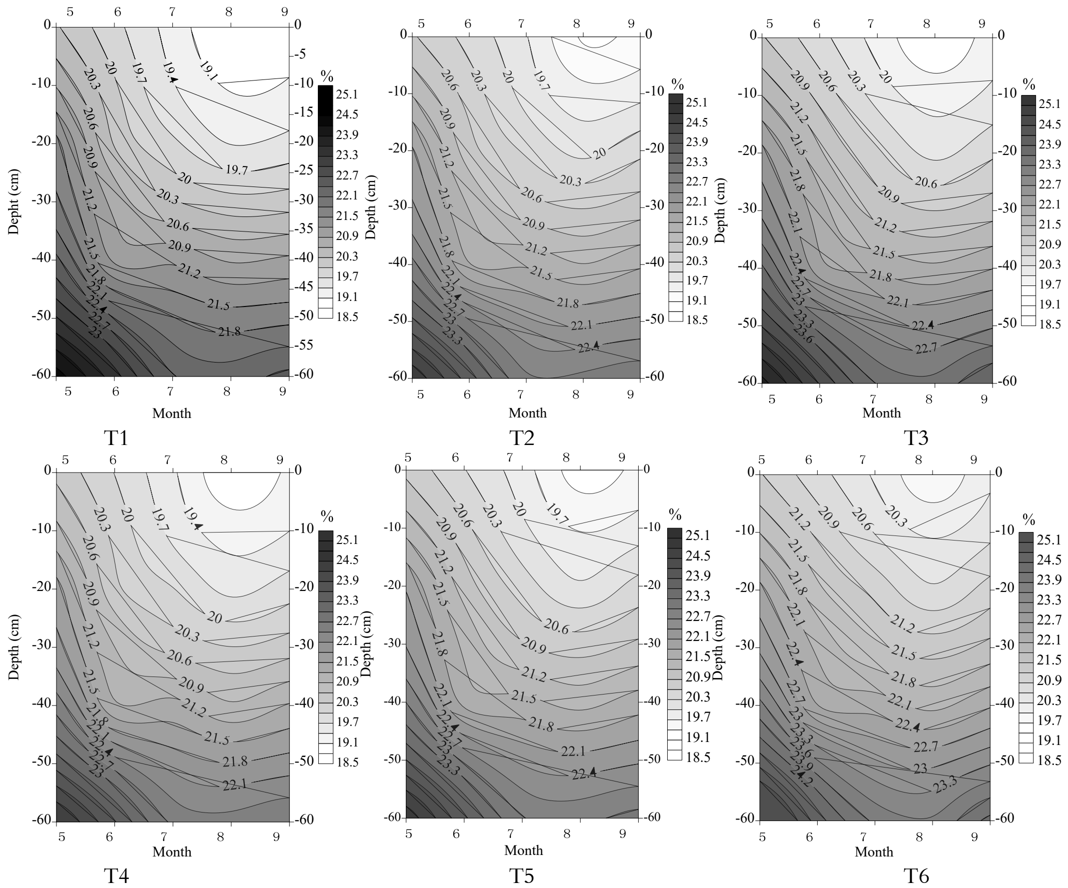

Fig. 1. Effects of different treatments on soil profile moisture of 0-60 cm soil layers

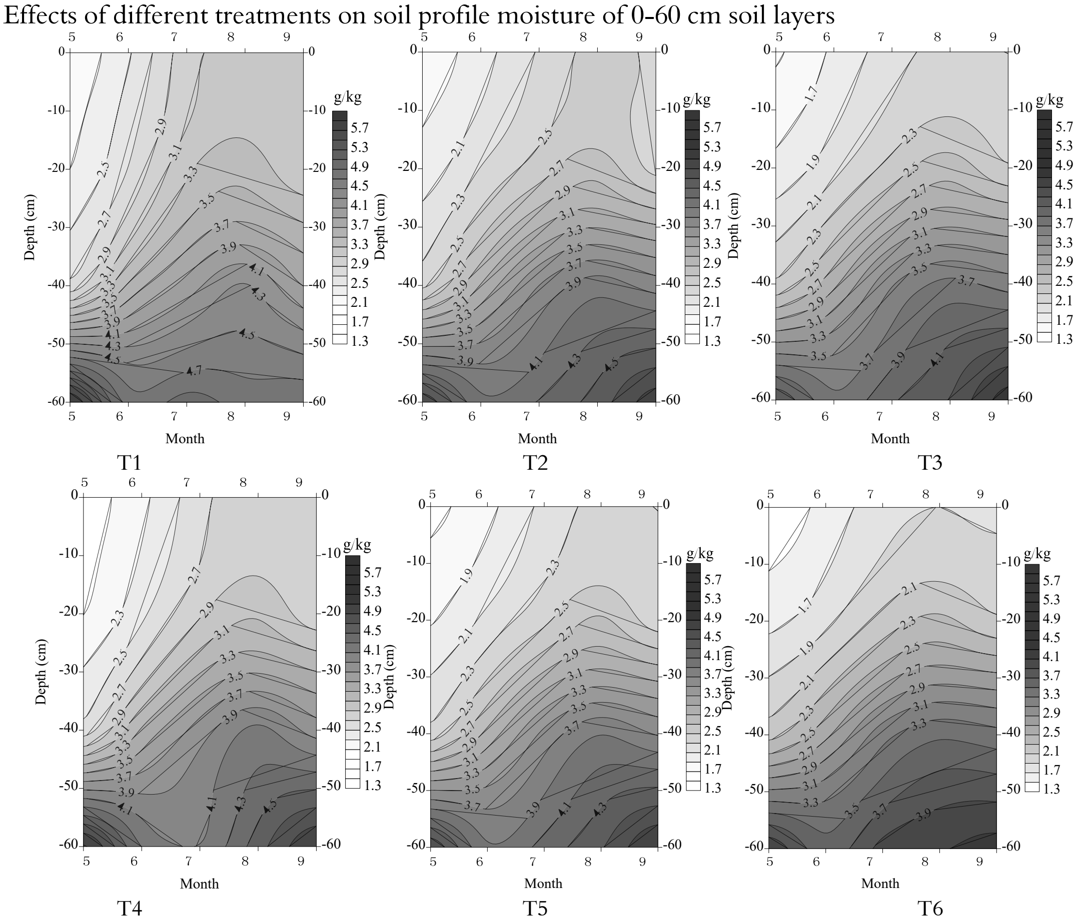

Fig. 2. Effects of different treatments on salinity of 0-60 cm soil layers

Table 4. Effect of different treatments on the distribution of salt ions in 0-60 cm soil layer (cmol/kg)

Year	Treatment	Na^+	Ca^{2+}	Mg^{2+}	K^+	CO2- 3	HCO- 3	Cl^-	SO2- 4
2016	T1	2.73 ± 0.08^a	0.52 ± 0.03^a	0.42 ± 0.02^a	0.15 ± 0.01^a	0.62 ± 0.05^a	0.72 ± 0.06^a	0.15 ± 0.04^a	1.52 ± 0.11^a
	T2	2.14 ± 0.07^{ab}	0.45 ± 0.02^a	0.38 ± 0.01^a	0.17 ± 0.02^a	0.58 ± 0.06^a	0.64 ± 0.05^a	0.17 ± 0.02^a	1.47 ± 0.12^a
	T3	1.92 ± 0.10^b	0.38 ± 0.04^b	0.39 ± 0.03^a	0.18 ± 0.01^a	0.55 ± 0.03^a	0.58 ± 0.05^a	0.16 ± 0.03^a	1.42 ± 0.09^a
	T4	2.37 ± 0.08^a	0.48 ± 0.05^a	0.41 ± 0.02^a	0.19 ± 0.01^a	0.57 ± 0.05^a	0.68 ± 0.04^a	0.14 ± 0.02^a	1.48 ± 0.08^a
	T5	2.03 ± 0.09^b	0.40 ± 0.03^{ab}	0.39 ± 0.01^a	0.16 ± 0.02^a	0.54 ± 0.05^a	0.66 ± 0.03^a	0.13 ± 0.03^a	1.44 ± 0.10^a
	T6	1.84 ± 0.04^b	0.33 ± 0.02^b	0.40 ± 0.02^a	0.15 ± 0.01^a	0.53 ± 0.04^a	0.55 ± 0.02^a	0.12 ± 0.03^a	1.38 ± 0.08^a
2017	T1	1.95 ± 0.07^a	0.38 ± 0.04^a	0.35 ± 0.03^a	0.14 ± 0.01^a	0.25 ± 0.03^a	0.32 ± 0.01^a	0.08 ± 0.05^a	0.82 ± 0.08^a
	T2	$1.64\pm0.04a^b$	0.27 ± 0.03^b	0.34 ± 0.02^a	0.16 ± 0.01^a	0.23 ± 0.02^a	0.29 ± 0.04^a	0.05 ± 0.02^a	0.75 ± 0.07^a
	T3	1.16 ± 0.06^b	0.23 ± 0.02^b	0.31 ± 0.01^a	0.17 ± 0.02^a	0.22 ± 0.02^a	0.25 ± 0.02^a	0.05 ± 0.01^a	0.68 ± 0.09^a
	T4	1.73 ± 0.03^a	0.36 ± 0.03^a	0.34 ± 0.05^a	0.15 ± 0.01^a	0.21 ± 0.01^a	0.30 ± 0.03^a	0.03 ± 0.01^a	0.78 ± 0.05^a
	T5	1.36 ± 0.07^b	0.25 ± 0.02^b	0.35 ± 0.04^a	0.18 ± 0.02^a	0.20 ± 0.01^a	0.29 ± 0.02^a	0.04 ± 0.01^a	0.72 ± 0.04^a
	T6	0.95 ± 0.06^b	0.18 ± 0.04^b	0.37 ± 0.03^a	0.17 ± 0.01^a	0.19 ± 0.02^a	0.24 ± 0.01^a	0.05 ± 0.01^a	0.63 ± 0.06^a

Note: Different letters indicate significant difference among treatments at 0.05 level and values = mean ± standard error, n = 3.

Soil Salt Ions

The effect of different treatments on the concentration of salt ions in the 0-60 cm soil layer is shown in **Table 4**. The concentrations of Na^+, CO2- 3, HCO- 3 and Cl^- in all treatments are lower than those in the original soil ($P<0.05$), but the concentrations of Mg^{2+} and K^+ have little change, while the concentration of SO2- 4 increases. In the first year, the concentration of Na^+ decreases by 67.4%-78.1%, and in the second year, the concentration of Na^+ decreases to 0.95-1.95 cmol/kg, among which, Na^+ in T6 treatment has the largest reduction ($P<0.05$). In the first years, the CO2- 3 and HCO- 3 in T6 treatment decrease by 31.2% and 65.8% respectively compared with the original soil, and it has the largest reduction in all treatments. In the second year, the concentrations of CO2- 3 and HCO- 3 inT6 treatment are 0.19 cmol/kg and 0.24 cmol/kg respectively. Cl^- has stable chemical properties and strong motion with water. Cl^- in ridging and furrowing treatments is lower than that in non-ridge treatments, indicating that ridging helps to collect water and promote the movement of Cl^- to deep soil.

In the first year, desulfurization gypsum was applied to increase the concentrations of Ca^{2+} and SO2- 4 in soil. The concentrations of Ca^{2+} and SO2- 4 in T1 treatment increased by 73.3% and 31.0% respectively, with the greatest increase in each treatment. Compared with the original soil, the concentrations of Mg^{2+} and K^+ had no significant difference ($P>0.05$), indicating that $Mg^{2+}$and K^+ were not easy to move with water.

Growth of Wolfberry

T6 treatment significantly promotes the growth of plant height and crown width of wolfberry, followed by T3 treatment, and the indexes of wolfberry in T1 treatment are the lowest among all treatments (**Table 5**). The survival rate, preservation rate, plant height, crown width and yield of wolfberry in T6 treatment are the highest and the T1 treatment is the lowest. There is no significant difference between T6 treatment and T4 and T5 treatments ($P>0.05$). In the first year, under the same irrigation quota, the average survival rate of wolfberry under ridge and furrow planting is 4.8%, 5.2% and 4.4% higher than that under the non-ridge treatment, and the average crown width is 10.0%, 7.7% and 8.7% higher than that under the non-ridge treatment. In the second year, the growth indexes and yield of wolfberry are higher than those in the first year. The yield of wolfberry under ridge and furrow planting is 9.6%, 8.8% and 9.4% higher than that under the non-ridge treatment under the corresponding irrigation amount. The results showed that under the same irrigation quota, ridging treatment could promote the growth and development of wolfberry better than non-ridge treatment, and the high irrigation quota was more beneficial to the growth and development of wolfberry under ridging or non-ridge cultivation mode.

DISCUSSION

In this experiment, the bulk density, pH value and alkalinity degree of all treated soils were lower than those before improvement. The improvement experiment of shrubs planted in saline-alkali soil by Lei et al. (2011) shows that the shrub root activity can improve soil pore distribution and reduce soil bulk density. Under the influence of shrub root activity, an optimum region of "low salinity and low alkali" is formed in 0~25 cm soil layer and 15 cm away from the trunk. The change trend is similar to that of this test. Hou's study (2014) also shows that the root activity of alfalfa and sweet sorghum can improve soil bulk density, and emphasizes that the improvement effect of soil bulk density is related to the depth of root distribution, interpenetration activity and root exudates of forest and grass plants. After two years of planting, the root system of wolfberry seedlings had interpenetration effect on the soil near the root system, which made the soil become relatively loose, and the

Table 5. Effects of different treatments on growth of wolfberry

Year	Treatment	Survival rate /%	Preservation rate /%	Height /cm	Crown width /cm	Yield / (t/hm^2)
2016	T1	87.3±1.42b	/	85.6±18.5b	112.3±18.6b	1.12±0.08b
	T2	88.2±1.38b	/	87.2±17.6b	119.5±20.4b	1.13±0.07b
	T3	89.5±1.47b	/	89.5±15.3b	122.7±19.7ab	1.14±0.04b
	T4	91.5±1.66a	/	92.5±14.8ab	123.5±18.5a	1.16±0.03a
	T5	92.8±1.57a	/	97.8±17.9a	128.7±20.3a	1.18±0.02a
	T6	93.4±1.32a	/	102.3±18.6a	133.4±21.5a	1.19±0.04a
2017	T1	/	83.8±1.32b	98.5±19.5b	135.2±20.4b	1.46±0.06b
	T2	/	85.4±1.43b	103.4±20.3b	138.7±21.6b	1.48±0.05b
	T3	/	86.8±1.38b	108.5±21.5ab	142.5±22.7a	1.49±0.03b
	T4	/	88.6±1.47a	117.3±22.4b	141.5±20.5ab	1.60±0.02a
	T5	/	90.5±1.35a	122.4±21.3a	145.7±23.8a	1.61±0.04a
	T6	/	92.4±1.38a	128.3±20.2a	149.6±25.3a	1.63±0.02a

Note: Different letters indicate significant difference among treatments at 0.05 level and values = mean ± standard error, n = 3. The yield of wolfberry is the yield of dried fruit

soil bulk density showed a decreasing trend. There was no significant difference in the effects of 2 kinds of wolfberry planting methods and different irrigation quotas on soil bulk density. The main component of desulfurization gypsum is $CaSO_4 \cdot 2H_2O$ (Wang et al. 2015). Applying it to soil will increase the concentrations of Ca^{2+} and SO2- 4. The adsorption capacity of Ca^{2+} on soil colloidal particles is stronger than that of Na^+, which results in the substitution reaction between Ca^{2+} and Na^+ adsorbed on soil colloidal particles, the reduction of Na^+ concentration and the reduction of soil alkalinity, and the inhibition of the dispersion effect of exchangeable Na^+ on soil clay (Wang et al. 2017). In addition, plant root activity releases organic acids to activate $CaSO_4$ and increase the content of SO2- 4 which is a strong acid radical and has a certain neutralization effect (Desutter et al. 2014). The precipitation reaction of HCO- 3, CO2- 3, and Ca^{2+} in soil results in the decrease of the content of HCO- 3 and CO2- 3 in soil, and the content of CO2- 3 and HCO- 3 is an important factor to determine the pH value of saline-alkali soil (Wang et al. 2015). In this study, it was found that the application of desulphurization gypsum effectively reduced soil alkalization degree and pH value compared with that before the improvement, and there was no significant difference among treatments. The effect of planting pattern and irrigation amount on soil pH and alkalinity degree was not obvious. However, Yang Jun et al. (2015) conducts the experiment to improve alkalized soil by applying desulfurized gypsum combined with leaching measures, which indicates that the more irrigation amount, the more obvious the decrease of soil pH value and alkalinity, which is consistent with the results of this experiment (Zhang et al. 2014). This may be caused by different soil types.

Planting in ridges and furrows can effectively store natural precipitation and irrigation water, regulate water in time and space, and maximize the accumulation and utilization of water resources, which has been confirmed in a large number of studies (Zhang et al. 2013a, 2013b, Zhao et al. 2014). The soil moisture content of ridging treatment is higher than that of non-ridge treatment, because ridging changes the earth surface, intercepts part of runoff, and collects rainfall. Increasing soil water storage contributes to the downward movement of water and water in furrow (planting area) is superimposed. Some studies have shown that with the increase of soil moisture content in furrows, the effect of lateral seepage under furrows is enhanced, and the vertical infiltration of water in furrows is enhanced, which is beneficial to the growth of plant roots in furrows and is also conducive to secondary salinization (Wang 2015). In this experiment, the wolfberry was planted in furrows. In summer, the coverage of wolfberry gradually increased, which could act as a shading effect, causing the temperature in the furrow to be lower than that on the ridge. Low temperature in the furrow can reduce the surface evaporation and inhibit the evaporation and salt return. In addition, summer rainfall accounts for nearly half of the annual rainfall. Ridges and furrows can accumulate natural precipitation and improve soil moisture content. It was also found that high irrigation rate was beneficial to salt leaching in 0~60 cm soil layer of soil profile. Salt accumulation in surface soil was obvious after low irrigation, because evaporation would cause salt migration from deep soil to the surface and increase soluble salt in upper soil when irrigation was small (Liang 2012).

The growth of plants is closely related to water, fertilizer, light and temperature. A large number of studies have shown that ridging planting is more conducive to plant growth and development than non-ridge planting (Li et al. 2011, Tabuada et al. 1995). Ridging changes the earth surface, and forms the soil micro topography with ridges and furrows. Ridge back forms water catchment surface, and runoff gathers along ridge back slope surface to form water superposition in ridge and furrow, so that water catchment to seedling root is fully absorbed and utilized, promoting the growth of plant root system in ridge and furrow, alleviating the adversity stress faced by plant growth (Fang et al. 2010). At the same time, ridging and furrowing planting changes the surface shape, resulting in the increase of surface area, sunlit area, the interface between soil and atmosphere, which can coordinate the soil water, fertilizer, air and heat conditions, improve plant growth environment, and promote plant growth and development (Gao et al. 2013). In this experiment, ridge and furrow planting changed the field micro-environment, improved the site conditions of wolfberry, and promoted the growth and development of wolfberry compared with the non-ridge treatment. It is noteworthy that although the soil salinity decreased with the increase of irrigation quota under this experimental condition, there was no significant difference in the growth indexes of wolfberry when the irrigation quotas were 9,375 m^3/hm^2 and 10,125 m^3/hm^2, and the experimental area was located in arid area with limited water resources. Too much irrigation will lead to a decrease in water use efficiency (Cantore et al. 2016), which is contrary to the principle of efficient water use. In addition, excessive irrigation can cause deep seepage, raise the groundwater level and increase the risk of secondary salinization (Seeboonruang 2012).

CONCLUSIONS

The application of desulphurization gypsum combined with leaching method can significantly reduce soil pH value, alkalinity degree and total salt content. The irrigation water, precipitation and other water can be collected in the furrow under the ridge and furrow planting mode, which can improves the soil moisture content. The soil salinity of ridging treatment in 0~40 cm soil layer is 14.2% lower than that of non-ridge treatment, and ridging planting helps to reduce soil salinity. The survival rate, plant height and crown width of wolfberry are higher than those of non-ridge treatment. When irrigation quotas are 9,375 m^3/hm^2 and 10,125 m^3/hm^2, the growth indexes of wolfberry have no significant difference, and the experimental area is located in arid area with limited water resources, so excessive irrigation not only wastes water resources but also increases the risk of secondary salinization. Therefore, the ridge and furrow planting of wolfberry and 9,375 m^3/hm^2 irrigation quota are suitable for the improvement of alkalized saline soil in Jingyuan, Gansu Province.

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