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Effect of irrigation on crop yield in Shendong saline alkali area

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ABSTRACT. *Aiming at the problem of soil salinization in Shendong mining area, based on the saline alkali soil improved by using desulfurized gypsum and fly ash, the influence of irrigation frequency and irrigation amount on salt removal and crop yield in the soil salinization area of loess subsidence area was studied in depth. In order to prevent the land salinization caused by improper irrigation and improve the saline alkali soil by planting crops, crops should be improved at the same time the yield provides a theoretical basis. In this paper, corn was used as a salt tolerant experimental plant. Under the same irrigation quota, different irrigation frequencies were set to study the relationship between irrigation frequency and the growth of vegetation, crop yield and soil salinization. The conclusions are as follows: (1) under the same irrigation amount, in a certain range, the relationship between irrigation frequency and vegetation growth and crop yield is that, with the increase of irrigation frequency, crop yield also increases; (2) under the same irrigation amount, the relationship between irrigation frequency and soil salinization is that high frequency irrigation can inhibit soil salinization High frequency irrigation has leaching effect on soil salt; (3) when the irrigation amount is not fixed, large amount of single frequency irrigation should be avoided.*

KEYWORDS: *Irrigation frequency; irrigation amount; saline alkali land; crop yield; Shendong mining area*

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1. Introduction

In Shendong mining area, the soil alkalinity is 40% - 60%, the soluble salt content is 0.2% - 0.5%, most of them are 0.2% - 0.3%. The salt composition is mainly Na2CO3 and NaHCO3, and pH values are mostly between 8.2 and 10.0. Chemical amendments, vegetation and irrigation frequency are of great significance to improve the saline alkali properties of soil. Therefore, it is very important to study the amendment and find out the relationship between the amount of irrigation, irrigation frequency and trees, shrubs, herbs, crops and so on. How to maintain water to meet the needs of vegetation growth and not cause soil salinization is the main purpose of this study. At the same time, in-depth study on the relationship between irrigation frequency and soil desalination and crop yield can provide an important basis for preventing soil salinization and maximizing crop yield.

Water has a crucial impact on crop yield, so the change of irrigation amount and irrigation frequency will also have a certain impact on crop yield.

J. Hunsaker [1], and other studies showed that the crop yield under low-frequency irrigation was not as good as that under high-frequency irrigation. The results showed that irrigation frequency had little effect on the output value and water utilization of flue-cured tobacco[2]. Carlos ball ester and Camilla vote[3] concluded that the shorter the irrigation frequency, the higher the maize yield. The effect of irrigation frequency on the yield of Chinese cabbage was higher than that of irrigation level [1,4]. Assouline. S [5] studies showed that irrigation frequency indirectly affected the root status of crops, and then affected water and oxygen absorption. Assoulin [6] research shows that irrigation frequency is an important reference index for formulating irrigation schedule. According to the research of breeze and Mvoshrefi [7], the irrigation quota is consistent, and the dry matter quality of drip irrigation is higher than that of sprinkler irrigation. Abalosa [8]showed that the fruit yield under high frequency irrigation was lower than that under low frequency irrigation. Goldberg and Shmuel [9]research shows that in sandy soil, excessive irrigation will lead to lower crop output value. Saleh m, Ismail and other studies showed that the fresh dry weight yield of alfalfa [10] [and pepper[11] [decreased with the decrease of irrigation amount. Kirda [12], the experimental study showed that similar conclusions were obtained. Bucks [13] and other studies show that the yield of cabbage in clay soil will decrease with the increase of irrigation times. Levin [14,15] and other studies showed that different irrigation frequency had no significant effect on apple yield when Apple was planted on similar clay. However, the irrigation quota remains unchanged, and high-frequency irrigation makes peanut [16,17] [and tomato [18] ,and other crops obtain high yield.

Soil water content and salt content have a great impact on vegetation, which is one of the key factors affecting the growth of vegetation, and the dynamic change of soil moisture also indirectly reflects the dynamic change of soil salt content from different angles.

Lei Du [19] and other studies have shown that unreasonable irrigation methods and irrigation management will lead to soil salinization, and it is necessary to avoid a

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single large amount of irrigation. The research of Rawlins and Sankara Reddi [20,21] showed that high frequency irrigation could optimize the growth conditions of crops. Ralwins[22], and other studies show that high frequency irrigation can better utilize soil water and fertilizer resources. High frequency irrigation can save water by reducing runoff. In areas with soil salinization problem, high frequency irrigation can inhibit soil salinity [23,24]. Goldberg [25]and other studies show that high frequency irrigation can set good soil water and oxygen conditions for the growth period of crops. According to Ropers [26], the yield of Alfalfa under secondary harvest and high-frequency irrigation was low due to the influence of high-frequency irrigation on soil ventilation. Some scholars believe that if the irrigation frequency is too high, the soil will be in the state of evaporation most of the time, and the evaporation will increase, so the growth of crops will be limited. The research shows that the consideration of irrigation and fertilization can better improve the water environment of agricultural ecological environment and the sustainability of production. The impact of irrigation on agriculture is obvious [27], but the impact of improper irrigation management on agricultural production environment has not been avoided.

To sum up, there are many researches on the effects of irrigation frequency and irrigation amount on soil desalination and crop yield in saline alkali soil at home and abroad, but there are also some scholars' research results conflicting. For example, some scholars think that high-frequency irrigation will make the soil in a state of evaporation, which will make the soil salinization serious, but some scholars think that high-frequency irrigation can reduce the soil salinity Soil evaporation, and for crop growth to establish a good foundation for soil growth. In this study, the saline alkali soil in Shendong mining area, Shenmu City, Yulin City, Shaanxi Province was taken as the research object. The effects of different irrigation frequency on soil salinization and crop yield were studied to provide theoretical basis for the future soil desalination[28,29].

2. Materials and Methods

2..1 Study area

The study area is located at the junction of Shanxi, Shaanxi and Inner Mongolia. Maowusu is in the north, the Loess Plateau is in the south, the Yellow River is in the south, and the Great Wall flies to the West. The total area of the whole city is 7635 square kilometers, which is located at 110.50 ° E and 38.83 ° n. The overall topographical characteristics of the mining area are high in the northwest and low in the southeast, with large drop. The river passes through both sides with narrow terrain. In the study area, the wind erosion is serious, the terrain is relatively flat, and the soil erosion is serious. The bottom of the foundation is the eroded and residual loess ridge terrain, the surface is undulating sand dunes, most of them are semi fixed quicksand and sheet quicksand. There are depressions of different sizes between the hills, surrounded by mountains on three sides, belonging to sandy desert grassland terrain, typical gully landform of loess area, where agriculture and animal husbandry are relatively concentrated. The annual average temperature is 7.3 ℃, the extreme

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minimum temperature is - 30.7 ℃, and the maximum temperature is 38.9 ℃. Temperate semi-arid continental climate, the annual average rainfall of 362 mm, often in the form of rainstorm concentrated in July to September, but the annual evaporation is huge, 2300mm, about six times of the precipitation. The soil is mostly sandy soil and loess, and the soil composition is mainly composed of silt and fine sand, and there are also some clay and sand particles.

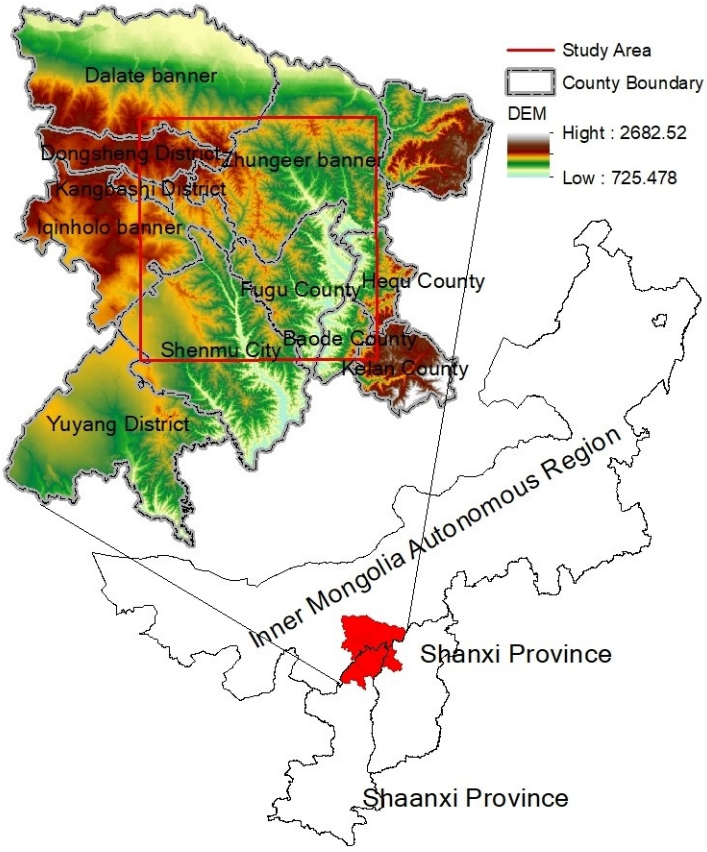

Fig 1. The location of the Shendong mining areas

2.2. Basic principle and experimental design

2.2.1 Basic principle

Desulfurized gypsum is a by-product of combustion power plant desulfurization. The main component is $CaSO_4$ and $2H_2O$, the content of which is about 90%, the water content is 6%, and the pH value is about 8.2. Desulfurized gypsum can improve

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salinized and alkalized soil, and scientific application of amendments is the key to success or failure of improvement.

Using desulfurized gypsum and other chemical modifiers to improve saline alkali soil belongs to a kind of chemical improvement measures. The soil contains clay and humus with small particle size. When the two react, a new colloid will be formed in the soil along with the reaction. When the colloid and other substances in the soil, such as Na + element in the soil, Na_2CO_3, $NaHCO^3$ and NaCl, will be formed in the soil Another new soil colloid with Na + is formed when it is contacted with colloid formed in alkaline soil. So, the sodium ions in the soil solution have active colloidal properties, which are just scattered in the soil pores to form an impermeable soil layer. This makes the soil permeability poor in saline alkali soil area, and soil is prone to soil rupture after water loss, which makes it difficult for plants to grow, and ordinary irrigation can not solve such a problem. However, Ca^{2+} produced by dissolving desulfurized gypsum can replace Na^{+}, which can make colloidal particles form particle clusters, thus improving saline alkali land.

2.2.2 Experimental design

Through the research, it is suggested that the application rate of soil exchangeable sodium (2-3cmol / kg) in 0-40cm soil layer is 9-10.5t/ha; that of soil exchangeable sodium (4-5cmol / kg) 0-40cm soil layer is 16.5-21t/ha; that of soil exchangeable sodium (6-7cmol / kg) 0-40cm soil layer is 25.5-28.5t/ha, and that of soil exchangeable sodium (8-9cmol / kg) 0-40cm soil layer is 31.5-36t/ha. The soil exchangeable sodium in Shendong area is mostly between 2 and 5cmol / kg, and the application amount of soil exchangeable sodium is guided by technicians on the spot.

In the process of practice, large-scale field application can be applied by spraying. It should be noted that it should be spread evenly according to the degree of alkali spots, and then ploughed with rotary plow for 30-40 cm, and should be as uniform as possible. Through the irrigation dissolves the modifier, causes the modifier and the soil to carry on the chemical action, completes the improvement process.

2.3. Statistical analyses

2.3.1 Soil properties

Three sampling areas are set up in the mining area, with three sampling points in each sample area, and three quadrats are taken from each sample point. Three samples are taken from the depth of 20cm, 40cm and 60cm from the surface layer downward, and then 1 / 4 samples are taken for analysis and test. A total of 81 soil samples were collected. Through indoor test, it is found that within the sampling points of Shendong mining area, the content of sulfate ion is the most, and the content of carbonate ion is the least. The content of bicarbonate ion is higher than that of chloride ion. According to the content of CO_3^{2-} and HCO_3^{-} above, the soil in the study area is saline alkali soil

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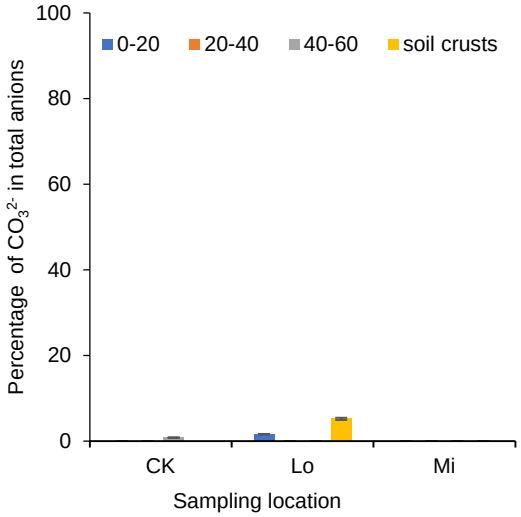
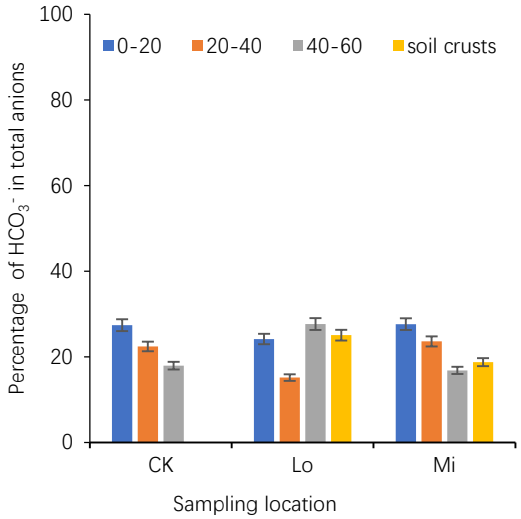
(Fig.2) The average value of total salt is 1.52, which belongs to moderate to severe saline alkali.



(a)



(b)

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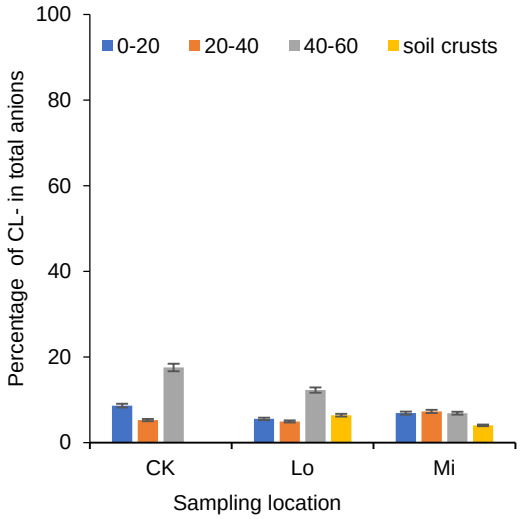
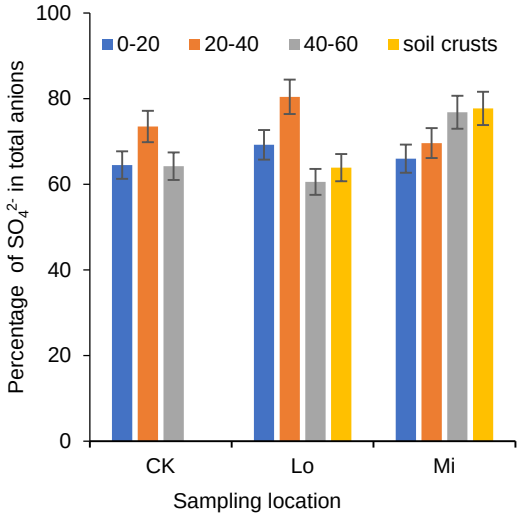


(c)



(d)

Fig 2. Percentage of soil anion content in Shendong Mining Area(CO32-; HCO3-CL1-; SO42-)

2.3.2 Soil structure

According to the calculation, within the research scope of Shendong mining area, sand accounts for 33.6%, silt accounts for 25.3%, clay accounts for 0.08% and clay powder accounts for 33.3% (Fig 3). All kinds of data are exported through ArcGIS

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software, and corresponding data are input into SPAW to establish soil model of Shendong Mining Area, which is used to simulate hydrological conditions. Soil water characteristics is one of the modules designed to estimate soil water holding capacity. The software describes the relationship between soil tension, electrical conductivity and soil moisture content through a set of equations, and inputs the content of silt, sand, organic matter percentage, etc.

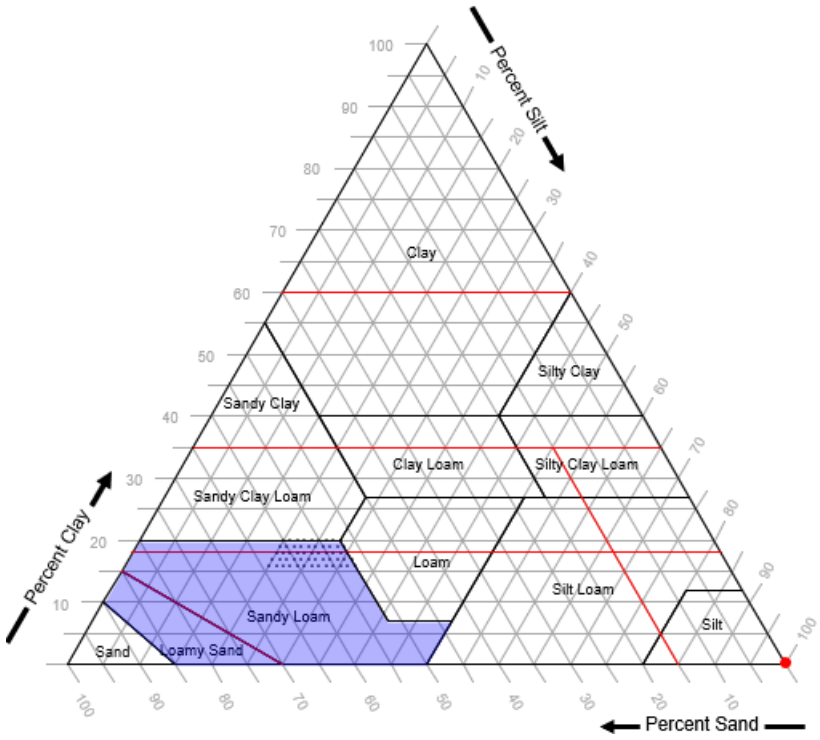

Fig 3. Soil texture map 1 in Shendong Mining Area

2.3.3 Vegetation water demand

Under normal water and fertilizer conditions, the water consumption of evapotranspiration in the whole growing period of crops is vegetation water demand, which generally includes plant transpiration and soil evaporation between plants. According to the observation of vegetation and crops, most of them are lack of water at the initial stage of growth. By the middle stage of plant growth, the requirements for various nutrient indexes and water content reach the highest in the whole growth period. At the later stage of plant growth, the crop yield is generally set, and the water demand of crops is also reduced the demand for water is no longer very strong. At the same time, the change law of crop coefficient is from small to large in the early stage, and then gradually smaller in the later stage.

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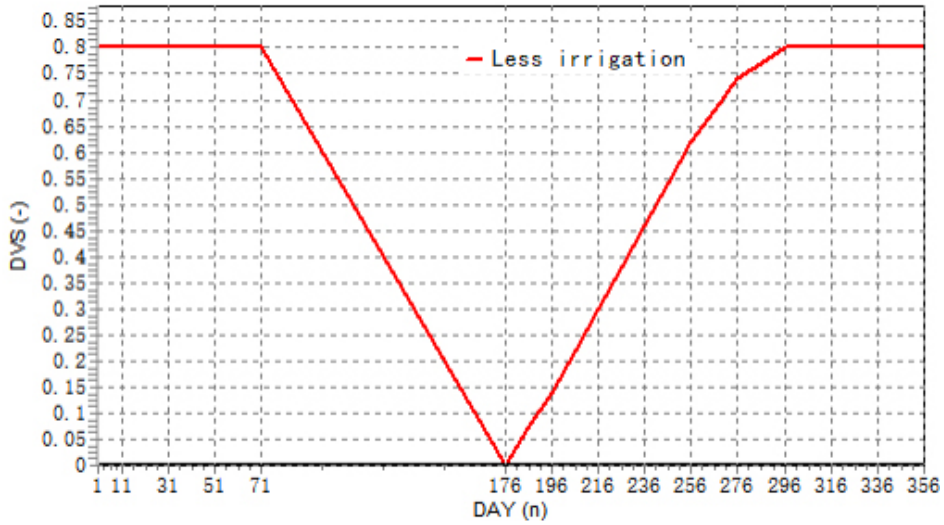
Table 1 Suitable Water Demand of Vegetation in Different Regions (Unit: mm) [30]

Region	Gansu	Shanxi	western Inner Mongolia	Yellow River Basin	Northwest China
crops	545.95	-	467.6	460	430-528

3. Results

3.1. Crop growth law of different irrigation methods

In the simulation experiment, corn was used as experimental material to simulate three irrigation situations(Fig 4) from WOFOST model [31,32], which were high irrigation amount and irrigation frequency, high irrigation amount and irrigation frequency, and low irrigation frequency. From the Fig below, we can roughly observe the characteristics of the growth and development stage of maize, which is generally in growth type, and remains stable under certain conditions. However, three different irrigation frequency and irrigation amount play different roles in different development stages of crops. With the increase of irrigation frequency, the situation of crop emergence stage intersecting with lower irrigation frequency is also ahead of the corresponding small range.



(a) Growth rule of maize under less irrigation levels

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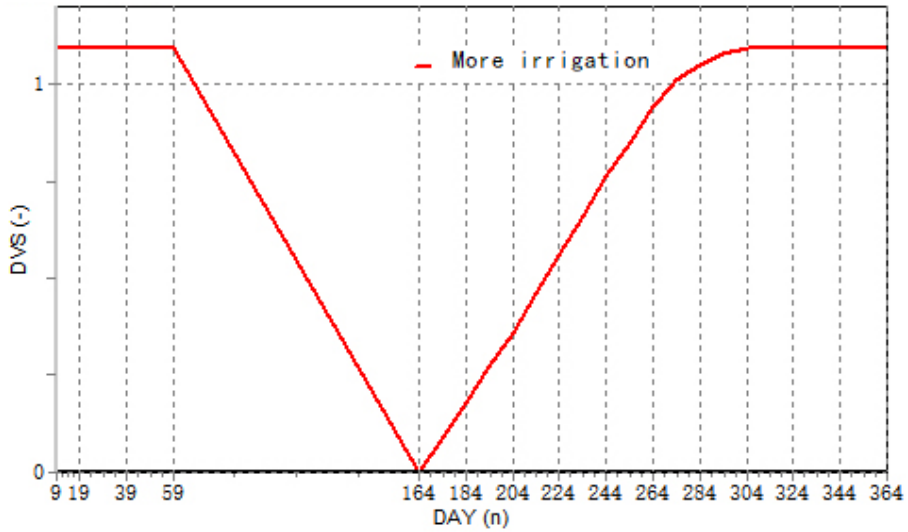
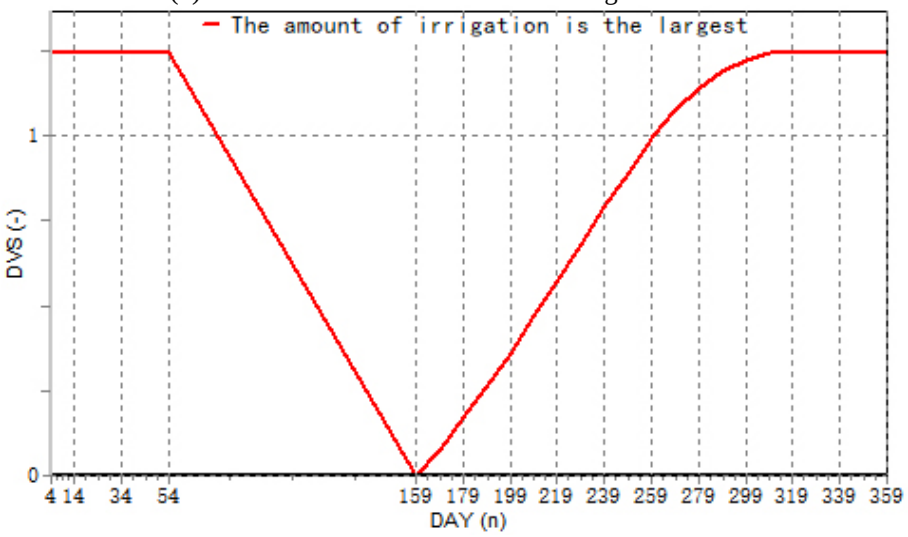


(b) Growth rule of maize under more irrigation levels



(c) Growth rule of maize under the amount of irrigation is the largest

Fig 4. Crop growth law under different irrigation levels

3.2 Change of leaf area index

Irrigation frequency and irrigation amount play an important role in affecting the growth and yield of crops. As shown in the following (Fig 5), with the increasing number of days, the leaf area accumulation of maize is also changing in a peak line, increasing first and then decreasing. It can be observed from the following Fig that the

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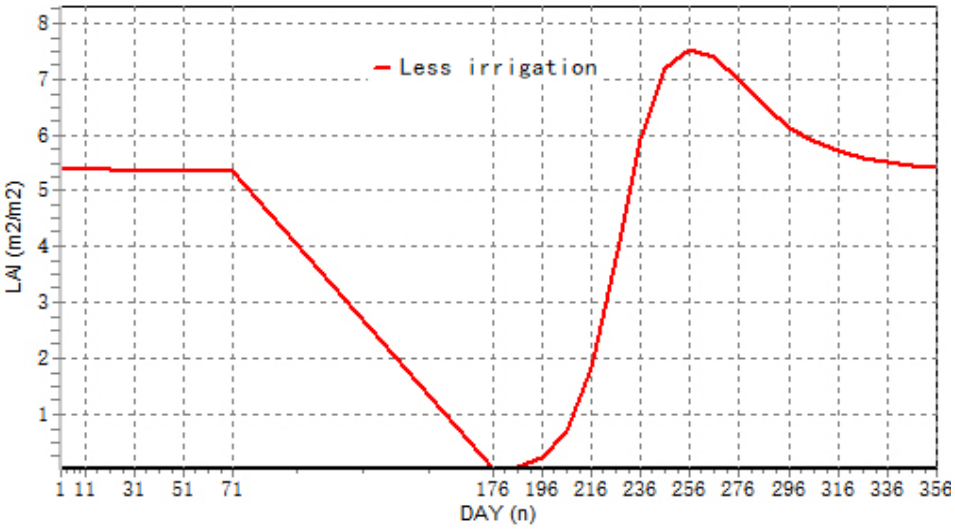
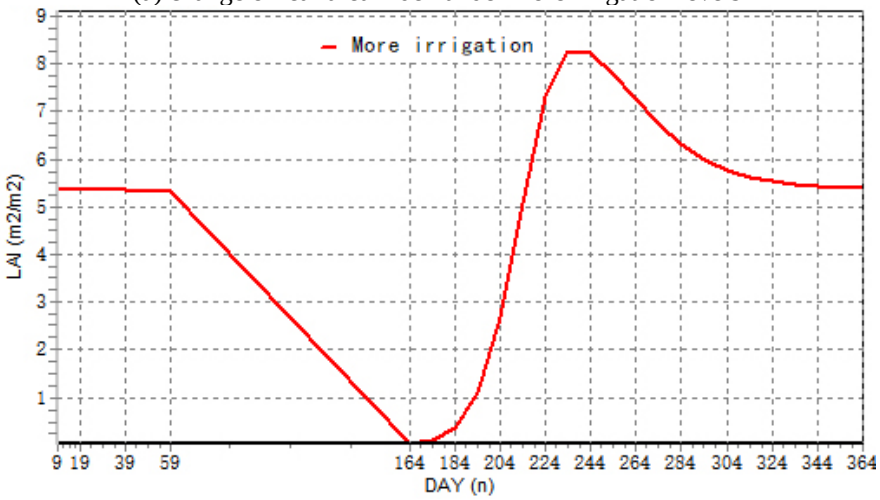
change curves of the three different conditions are relatively similar, but the initial accumulation date of leaf area of the three conditions are obviously different. In the simulated crop model, the initial accumulation date of leaf area with low irrigation frequency was about 186 days and reached the highest point on 256 days. The initial date of leaf area accumulation with higher irrigation frequency and irrigation amount was 169 days, and reached the highest point between 234 and 244 days. The initial date of leaf area accumulation with high irrigation frequency and irrigation amount was 169 days and 229 days respectively It reached the highest point of leaf area accumulation. It can be seen that the gradual increase of irrigation frequency and irrigation amount can promote the leaf area accumulation of crops, which can advance the leaf area accumulation date of crops.



(a) change of leaf area index under more irrigation levels



(b) change of leaf area index under less irrigation levels

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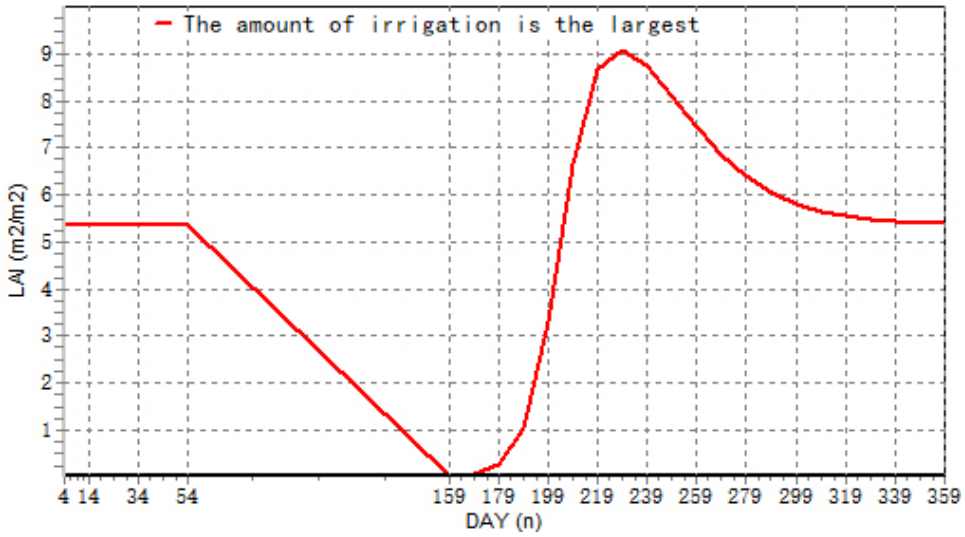

(c) change of leaf area index under the amount of irrigation is the largest

Fig 5. Change of leaf area index under different irrigation levels

3.3 Dry matter accumulation

With the completion of corn sowing, the dry matter quality on the ground also changes dynamically with the advance of the days. The change of irrigation amount and frequency also has an impact on the dry matter quality of corn ground. Under the same three conditions, the dry matter mass on the ground of maize began to accumulate, gradually changed, and began to rise slowly. After 40 days, the dry matter accumulation on the ground of maize began to increase rapidly, and reached the maximum at 130 days after emergence and maintained stable. In the following figure, it can be observed that with the increase of irrigation frequency and irrigation amount, the emergence date and initial dry matter accumulation date of crops are promoted, and the accumulation of dry matter yield is improved. Under the condition of low irrigation frequency and irrigation amount, the dry matter accumulation on the ground reaches the maximum on 296 days, which is about 7000kg / ha(Fig 6 a), Under the condition of higher irrigation frequency and irrigation amount, the dry matter accumulation on the ground reached the highest value in 290 days, which was about 14624kg / ha(Fig 6 b). In the case of the highest irrigation frequency and irrigation amount, the dry matter accumulation on the ground reached the highest value in 290 days, about 11000kg / ha(Fig 6 c). It can be seen that irrigation frequency and irrigation amount have an effect on the initial date of dry matter accumulation, but not on leaf area accumulation, but on the dry matter accumulation. With the increase of irrigation frequency and irrigation amount, the accumulation of dry matter quality on the ground is also gradually improved, but too high irrigation amount is not suitable, on the contrary, it will inhibit the accumulation of dry matter, and low irrigation

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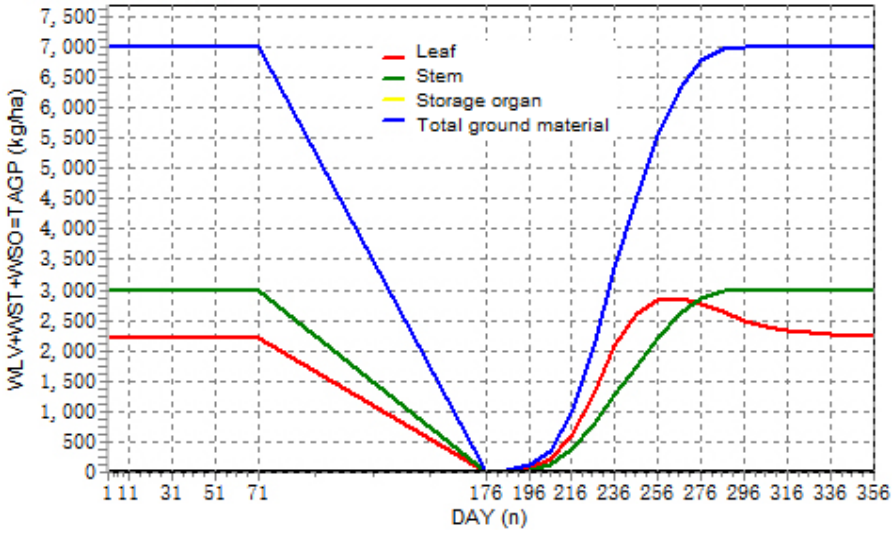
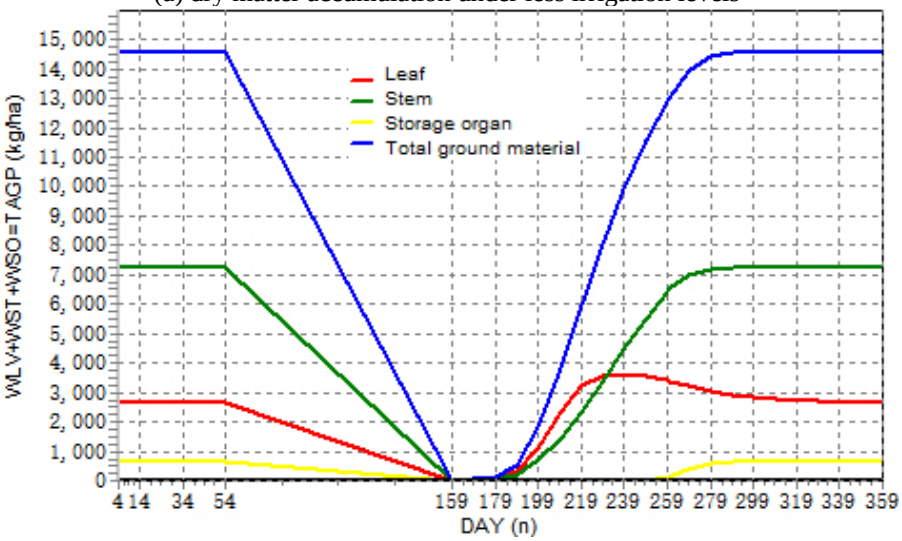
frequency is not conducive to the accumulation of dry matter quality of corn, affecting the normal growth of corn.



(a) dry matter accumulation under less irrigation levels



(b) change of leaf area index under more irrigation levels

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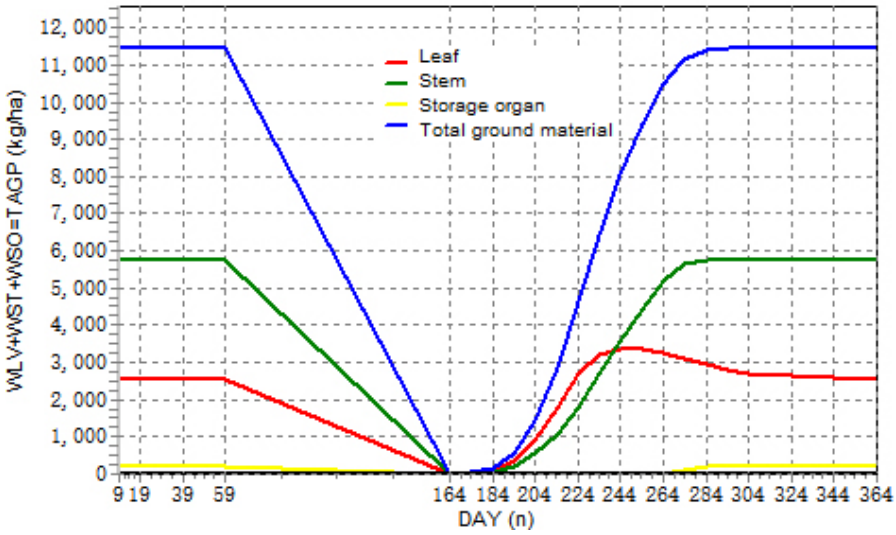

(c) Dry matter accumulation under the amount of irrigation is the largest

Fig 6. Dry matter accumulation under different irrigation levels

3.4 Crop yield

Compared with the experimental data in the above table and the yield change trend in the Fig below, the final harvest yield of maize is also different under different irrigation frequency and irrigation amount. In a certain range, with the increase of irrigation frequency, crop yield is also increased. When the irrigation frequency and irrigation amount were more, the output value of maize reached the maximum, reaching 29300kg / ha. When the irrigation frequency and irrigation amount were less, the output value of maize decreased significantly, and the final output value was only 17575kg / ha. When the irrigation frequency and irrigation amount were too much, the maize yield also showed an increasing trend, which was close to the yield under moderate irrigation frequency and irrigation amount, But compared with the final yield, it can be clearly found that high frequency irrigation and excessive irrigation caused the inhibition of crop yield.

4. Discussion

4.1 Improvement of soil by desulfurized gypsum and fly ash

Many research results show that the effective measures to prevent soil salinization and improvement of saline alkali land are as follows: the whole land is deep turned[16], fertilizer[4,33,34] is used reasonably and irrigation system is mades[3,16,21,30]. The improved method of desulfurized gypsum[35] is to replace

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the sodium ions in the soil with calcium ions. The adsorption capacity of the two ions to soil particles is different, so the structure of the soil is changed, and the desalting effect is achieved.

For the improvement of the saline alkali soil in Shendong mining area, the results can be obtained from the above data. It is suggested that organic fertilizer should be applied in combination with desulfurization gypsum, and it is suggested that about 1 ton per mu be applied. During the planting and growing of crops, seed fertilizer and proper fertilizer (nitrogen and phosphorus fertilizer) should be applied together. Organic fertilizer should be applied in afforestation land to supplement the lower fertility level of alkaline soil[36-38] (through the determination, most of the soil effective nitrogen is less than 15mg/kg, and soil available phosphorus is less than 6mg/kg). During the growth of crops, field management such as medium tillage and weeding should be carried out, and timely irrigation should be carried out in case of drought.

4.2 Effect of irrigation frequency on soil salinization and crop yield

In this experiment, orthogonal experiment design is selected to avoid redundant experiments, and representative combination is tested, so as to select the optimal combination. Because of the orthogonality of the orthogonal table, the experimental points of the orthogonal test are very representative, so the conclusion can be roughly seen through the whole part.

Based on the improvement of soil with the use of improvers, the influence of water on the improvement of crops in saline alkali land is very important. When the irrigation frequency is fixed, the excessive irrigation amount leads to the decrease of crop and vegetation yield, and the excess water makes the improved land suffer from excessive surface water, which results in the evaporation of water for most of the time, which makes the secondary salinization of soil serious, and the low irrigation water volume cannot provide normal water fertilizer and thermal environment for crops, and cannot provide the crops with the right water and fertilizer When suitable growth environment, crop yield is reduced. When the irrigation amount is in the right state, it provides a good hydrothermal environment for crops, and can maintain the normal system cycle of soil. Then when the irrigation amount is certain, high frequency irrigation can promote the growth and development of crops and the yield of crops. Although the water demand of different vegetation is different in different periods and their requirements for irrigation times are different, the common point is that the high or low irrigation frequency will lead to the decrease of crop and vegetation yield, and all vegetation avoid large irrigation in one time.

5. Conclusions

Under the same irrigation amount, the relationship between irrigation frequency and vegetation growth and crop yield is that, with the increase of irrigation frequency, the crop yield also increases; Under the same irrigation amount, the relationship

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between irrigation frequency and soil salinization is that high frequency irrigation has inhibition effect on soil salinization, and high frequency irrigation has leaching effect on soil salt; In the case of the uncertainty of irrigation amount, it is necessary to avoid large amount of irrigation in single frequency. Water is an important factor to determine crop yield, so suitable irrigation system is conducive to promote the maximum nutrient absorption and yield of crops, improve the efficiency of soil water and fertilizer utilization, and reduce the risk of soil nutrient leaching.

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Conflicts of Interest: The authors declare no conflict of interest.

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