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Study on the Improvement Effect of Desulfurization Gypsum in Saline-alkali Land

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Abstract. As the waste of coal-fired power plant, desulphurization gypsum is mainly composed of $CaSO_3$ and $CaSO_4$, which can replace Na+ in saline-alkali soil to improve saline-alkali soil. In order to study the effect of different dosage of desulfurization gypsum on the improvement of saline-alkali land, field experiments were carried out in Duiziliang Town, Dingbian County, northern Shaanxi Province, using drought-tolerant and Saline-Alkali-Tolerant local crop Mint as the test crop. The results showed that the application of desulfurization gypsum could reduce the harm of salt and alkali in soil to the germination, emergence and growth of millet seeds. Compared with the application of desulfurization gypsum, the soil pH value of plough layer (0-30cm) decreased by 4.2%-9.0%, and the total water soluble salt decreased by 6.6%~33.0%. In addition, the application of desulfurization can promote the growth of mint in saline-alkali soil. Compared with the application of desulfurization gypsum, the dry biomass of the above-ground part of mint increased by 28.9%~48.9%, the plant height increased by 24~30 cm, and the yield per mu increased by 36.91~65.28 kg. The results showed that the application of 20 t hm^{-2} desulphurization gypsum could improve the physical and chemical properties of saline-alkali soil in northern Shaanxi and obtain higher yield for moderate and severe saline-alkali land. It was suggested that the application of desulphurization gypsum should be popularized in saline-alkali land in northern Shaanxi.

1. Introduction

China's coal-fired power plants emit hundreds of millions of tons of desulfurization gypsum every year. Most of them are abandoned in the open air, which not only occupies a large amount of land, but also causes secondary pollution to the environment and wastes a lot of resources. North Shaanxi is rich in coal resources, and its annual output of desulfurization gypsum from coal-fired power plant waste is also very huge. In order to alleviate the occupation of land resources and secondary pollution to the environment in the storage process of desulfurization gypsum and broaden the application scope of desulfurization gypsum, it is necessary to utilize it as a resource

At the same time, the rapid development of society leads to the scarcity of land resources, among which the problem of land salinization is very prominent in China. The area of saline-alkali land in China is about 7.6 $*10^6$ hm^2, and nearly one fifth of cultivated land is salinized or secondary salinized [1]. Because Ca_{2+} in desulphurization gypsum can replace Na+ in saline-alkali soil to improve saline-alkali soil, and gypsum has no toxic side effects on plants, moderate solubility and easy to transport, gypsum has become the most common saline-alkali soil improver [2]. Using desulfurized gypsum in improving saline-alkali land not only solves the problem of using desulfurized gypsum, but also solves the problem of improving saline-alkali land, and contributes to the diversification of natural ecology and sustainable development.

In recent years, domestic and foreign scholars have carried out in-depth research on the improvement of saline-alkali land by desulfurization gypsum, and achieved some results. Chen Changhe et al. put forward the use of coal-fired flue gas desulfurization waste and the method of improving alkaline soil, and applied for patent for invention; Jiang Tongxuan et al. [3] took desulfurization gypsum of coal-fired power plant as test material, and studied the effect of desulfurization gypsum on saline-alkali soil salt transport under different irrigation volume by soil column simulation test method; Lu Jiandong et al. aimed at saline-alkaline soil in Ningxia Hui Autonomous Region. Severe problems were discussed. The effects of four integrated models of saline-alkali soil improvement technology with desulfurization gypsum as the core on soil physical and chemical properties and rice growth were studied.

In recent years, domestic and foreign scholars have carried out in-depth research on the improvement of saline-alkali land by desulfurization gypsum, and achieved some results. Chen Changhe et al. proposed a method of improving alkaline soil with desulfurization waste and applied for a patent for invention. Jiang Tongxuan et al. [4] studied the effect of desulfurization gypsum on salt transport in saline-alkali soils under different irrigation volumes using desulfurization gypsum of coal-fired power plants as test material and soil column simulation test method. Aiming at the serious problem of soil salinization in irrigation area of Ningxia Hui Autonomous Region, Lv Jiandong studied the effects of four integrated models of saline-alkali soil improvement technology with desulfurization gypsum as the core on soil physical and chemical properties and rice growth.

The formation of saline soil is a long-term and complex process. Due to the great differences in the parent materials and natural environment of saline-alkali soil in different regions, the effect of saline-alkali improvement is quite different under different dosage of desulfurization gypsum. [5] In order to provide theoretical reference and technical basis for the resource utilization of desulfurized gypsum and the improvement and utilization of saline-alkali land in northern Shaanxi, the experiment of improving saline-alkali land with cold-tolerant, drought-tolerant and Saline-Alkali-Tolerant millet was carried out in the arid area of Dingbian, northern Shaanxi Province, and the dynamic changes of soil physical and chemical properties and crop growth under different dosage of desulfurized gypsum were compared and analyzed.

2. Materials and methods

2.1. Survey of Research Areas

The experiment was conducted in Baitugangzi Village, Duiziliang Town, Dingbian County, Yulin City, Shaanxi Province. The area is characterized by strong wind and sand in spring, drought in summer, continuous rain in autumn and severe cold in winter. The terrain and physiognomy belong to windy sandy beach area. The northern river belt is vertical and horizontal, with a large area of saline-alkali land in the middle. Soil samples from the study area were collected before the start of the experiment and the basic physical and chemical properties of the soil were determined. The results are shown in Table 1.

Table 1. Basic physicochemical properties of soil

Layer thickness (cm)	pH	Salt content (g kg^{-1})	Organic matter (g kg^{-1})	Total nitrogen 0.05-2	Available phosphorus (mg kg^{-1})	Available potassium (mg kg^{-1})
0~20	9.21±0.14	6.84±0.12	2.47±0.05	0.25±0.05	0.25±0.04	32.77±3.02
20~30	9.19±0.09	7.06±0.10	2.28±0.03	0.46±0.04	0.34±0.02	33.02±2.14
30~50	9.01±0.21	7.11±0.11	4.47±0.03	0.32±0.04	0.39±0.03	38.75±2.03
50~70	9.14±0.12	6.98±0.07	2.53±0.05	0.31±0.05	0.43±0.07	19.56±1.14

2.2. Experimental design
Combining the climate, topography, soil salinization characteristics and farming habits of the study area, field experiments were conducted on a representative area (moderate and severe saline-alkali land) in the project area. According to the different dosage of desulfurized gypsum, four treatments T1, T2, T3 and T4 were set up. The dosage of desulfurized gypsum was 0, 10, 20 and 30 t hm-^{2}, respectively. Millet was planted by artificial ditching with a row spacing of 20 cm and a seeding amount of 1.5 kg mu^{-1}. The area of the experimental plot is 3 m *5 M. The cultivar of millet is "Yumi No. 3" developed by Yulin Agricultural Science Research Institute of Shaanxi Province. In the study area, 20 cubic meters of agricultural fertilizer were used as base fertilizer at one time, 75 kg diammonium phosphate topdressing per hectare was applied at sowing time, and 37 kg urea per hectare could be topdressed once with middle tillage and irrigation at jointing and booting stage.

2.3. Sample Collection and Processing
Soil samples were collected in different layers, and the changes of soil moisture, pH, conductivity, salinity and nutrients were monitored through laboratory tests. Sampling depth was set as 0-10, 10-20, 20-40, 40-60, 60-80 and 80-100 cm, respectively. The changes of water content, pH, conductivity, salinity and soil nutrients in 0-100 cm soil were monitored. Five representative plants were selected in the experimental plot, and their height was measured by tape measure every month and weighed by drying.

3. Analysis of Soil Problems in Research Areas

3.1. Causes and Main Periods of Soil Salt Damage

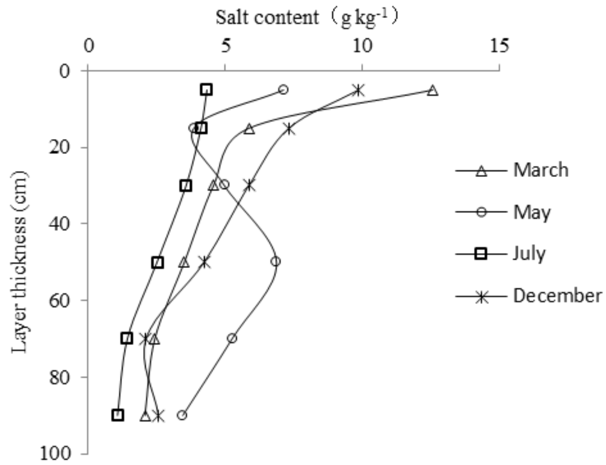

Fig. 1 Profile distribution of soil salinity in the study area

According to Fig. 1, winter and spring are the main periods of soil salt damage in Dingbian County. In March and December, the salt content of surface soil is 12.57 g/kg and 9.86 g/kg, respectively. The reason is that in winter and spring, the surface vegetation is sparse, precipitation is sparse and evaporation is large, which leads to serious salt accumulation in the surface soil of farmland before next year's sowing.

3.2. Causes and Main Periods of Soil Alkali Damage

According to the observation and analysis results of soil pH (Fig. 2), soil alkali damage is serious in the study area. The soil pH values of 0-100 cm in March, May, July and December all exceed 8.5, reaching alkaline soil, and most of the shallow soil pH values exceed 9.0, which is strong alkaline soil. During the observation period, the soil pH in Baitugangzi Village project area was higher, which was very unfavorable to the crop growth process.

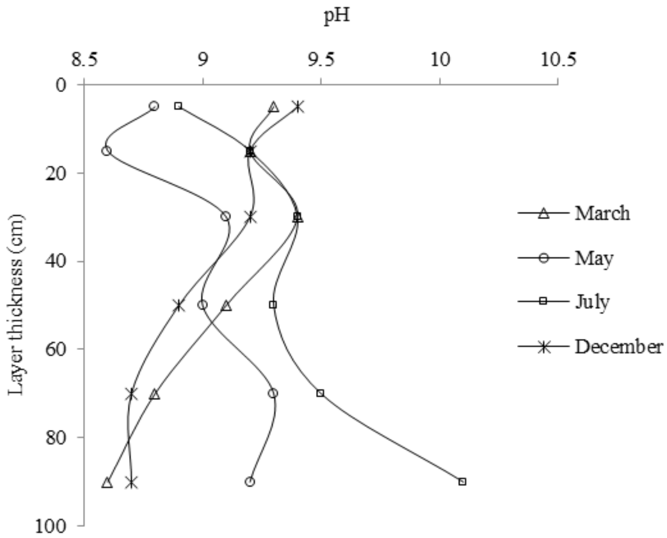

Fig. 2 Profile distribution of soil pH in the study area

4. Interpretation of results

4.1. Profile Distribution Characteristics of soil salinity

Affected by the strong evaporation process of soil surface, the soil salinity of different desulfurization gypsum application rates showed obvious surface accumulation (Figure 3). Because the sampling plots are close to each other, there is no obvious difference in soil salinity among different tillage plots. The salinity of 0~10 cm soil layers in T3 and T4 blocks was 2.98 g/kg and 3.32 g/kg respectively, which were in moderate salinity. The salinity of 0~10 cm soil layers in T1 and T2 blocks was 4.15 g kg^{-1} and 4.45 g kg^{-1} respectively, which were in severe salinity. Therefore, adding desulfurization gypsum into saline soil can reduce the salinization degree of saline-alkali surface soil. Except that the salinity of 80~100 cm soil layer in T2 field exceeded 0.4% and reached the degree of severe salinization, the salinity of 20~100 cm soil layer in each treatment was in the degree of mild salinization.

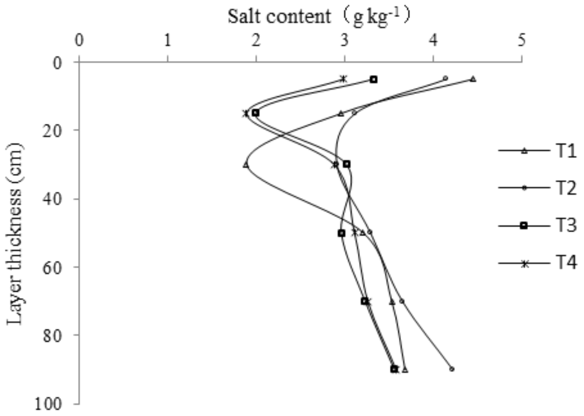

Fig. 3 Distribution of soil salt content in profile

4.2. *Profile Distribution Characteristics of Soil pH*

Different dosage of desulphurization gypsum had obvious effect on soil pH in plough layer (0-30 cm) (Fig. 4) the soil pH value of each treatment decreased gradually with the increase of desulfurization gypsum application. The average values of soil pH of T1, T2, T3 and T4 were 9.23, 8.84, 8.42 and 8.40, respectively. In addition, the soil pH values of 30-100 cm in different treatment plots increased gradually with the deepening of soil depth. When the soil depth was between 80 cm and 100 cm, the soil pH values of T1, T2, T3 and T4 were 9.56, 9.47, 9.32 and 9.28, respectively. The soil pH values were higher than 9, and the alkalinity was serious, which was harmful to crop growth.

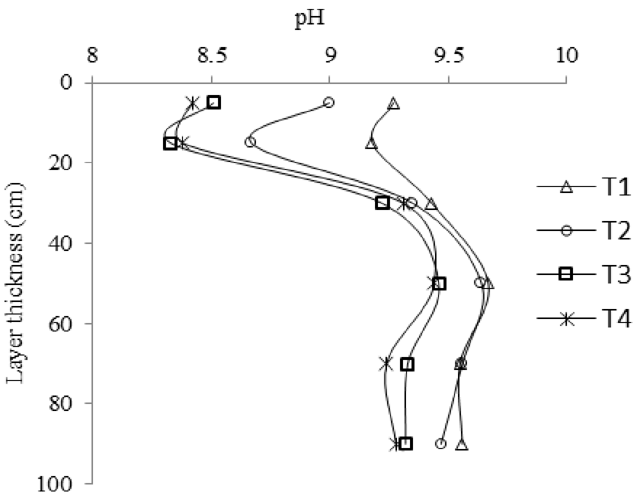

Fig. 4 Distribution of soil pH in profile

4.3. *Dry Matter Weight of Above Ground of Millet Plants*

The above-ground dry matter weight of millet plants treated with different treatments was shown in Table 2. The relationship between dry matter weight and desulfurization gypsum was basically the same in the growing (July) and maturing (September). With the increase of desulfurization gypsum content, the dry matter weight of millet plants increased. The above-ground dry matter weight of T4 was the largest at maturity stage, with an average weight of 6.73 g per plant. The above-ground dry matter weight of T3 was slightly less than that of T4, while that of T1 was the smallest, with an average weight of only 4.43 g per plant.

Table 2. Dry weight per plant of above ground part of millet treated by different experiments

Treatments	T1	T2	T3	T4
July 15th	0.8 g	1.2 g	1.5 g	1.7 g
September 15th	4.5 g	5.8 g	6.6 g	6.7 g

4.4. Variation of Millet Plant Height

Variation characteristics of millet plant height under different treatments are shown in Table 3. During each observation period, the growth of millet in June was slower at seedling stage. The period of rapid growth of millet is from July to August with higher temperature, more precipitation and better soil moisture condition. Physiological growth rate of millet slowed down in September. Overall, the plant height of all treatments (T2, T3, T4) with FGD gypsum was significantly higher than that without FGD gypsum. Among them, the plant height of T3 treatment was the highest, reached 126 cm in September, and the plant height of T4 treatment was slightly lower than that of treatment T2.

Table 3. Plant Height of Millet Treated by Different Experiments

Treatments	T1 (cm)	T2 (cm)	T3 (cm)	T4 (cm)
June 15th	9	12	12	10
July 15th	22	24	28	27
August 15th	78	116	121	108
September 15th	96	120	126	122

4.5. Millet Yield

Yield is the ultimate embodiment of plant growth and development. It was found that different dosage of desulphurization gypsum had obvious effects on the yield of millet: the highest yield per mu of treated T3 was 151.68 kg, the highest yield per mu of T 4 was 143.36 kg, the yield of T2 was 123.31 kg, and the lowest yield per mu of T1 was 86.4 kg. The application of desulfurized gypsum can significantly increase the yield of chyme in saline-alkali soil, but the relationship between the dosage of desulfurized gypsum and the yield of chyme is not simple linear , so it can not blindly increase the application of desulfurized gypsum.

5. Concluding Recommendations

The results showed that compared with the control, the soil pH value of plough layer (0-30cm) decreased by 4.2%-9.0% and the total amount of water-soluble salt reached the bottom of 6.6%-33.0%, which alleviated the harm of salt and alkali to the germination, seedling emergence and growth of millet seeds. The application of desulfurization could promote the growth of mint in saline-alkali soil. Compared with the control, the dry biomass of the above-ground part of mint increased by 28.9%~48.9%, the plant height increased by 24~30 cm, and the yield per mu increased by 36.91~65.28 kg. For moderately and severely saline-alkali land, 20 t of desulfurized gypsum per hectare can promote the growth and development of millet and obtain higher economic yield, and the effect of improving soil pH is obvious. It is suggested that the application of desulfurized gypsum should be popularized.

Millet is a high-quality drought-tolerant and Saline-Alkali-Tolerant crop widely planted in northern Shaanxi. During the long-term growth and evolution process, it adapted to the arid and semi-arid natural environment conditions in northern Shaanxi and formed the characteristics of cold-tolerant, drought-tolerant and Saline-Alkali-Tolerant soils. According to the physical and chemical properties of soil and climatic conditions in Dingbian County, Shaanxi Province, expanding the scale of medium and severe saline-alkali land and improving the cultivation of millet have important reference value for the establishment of eco-agricultural economic model [6].

Saline soil improvement is also a long-term and complex systematic project. Any single improvement measure has its own applicable conditions, technical advantages and limitations [7]. In view of the problems of drought, wet, salt and alkali damage in the study area, and the low content of soil nutrients and organic matter in newly-added cultivated land, it is suggested that the appropriate irrigation and fertilization amount of different crops be studied to effectively control soil salinity through rational irrigation and improve the utilization efficiency of fertilizers. In addition, in view of the current situation of soil alkalinity, it is suggested to continue to study the effect of desulfurization gypsum on saline-alkali soil, and to explore the effects of the application period of desulfurization gypsum on crop growth and soil physical and chemical properties, as well as the appropriate dosage of desulfurization gypsum in different salinity-alkali soils.

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