Study on the Combined Application of Four Solid Waste Amendments to Improve the Saline-Alkali Soil in the Mining Area

--Taking Shendong Mining Area as an Example

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Abstract

Aiming at the problems of high alkalization and prominent single salt toxicity in the saline-alkali soil in Shendong mining area, this article selects desulfurized gypsum and fly ash as well as mixtures of sludge and slag from a wide range of sources and low prices as modifiers. Potted test method, the application rate of desulfurization gypsum, fly ash, sludge and slag mixture to improve alkalized soil was tested by planting alfalfa. Potted experiments were conducted to study the changes in seedling emergence, plant height, number of stalks, and soil physicochemical properties of alfalfa at seedling stage under different combined application levels of desulfurized gypsum, fly ash, sludge and slag mixture. Studies have shown that the application of desulphurized gypsum and fly ash, as well as the mixture of sludge and slag, can significantly improve the physical and chemical properties of the soil in the mining area, adjust the ion balance in the soil, reduce the toxicity of single salt and physiological drought, and have a certain promotion effect on plant growth.

Keywords

Desulfurized Gypsum; Fly Ash; Salinized Soil in Mining Area.

1. Introduction

The Shendong mining area is located in the southeast of the Ordos Plateau, on the north side of the Loess Plateau in northern Shaanxi, and on the southeastern edge of the Mu Us Desert[1]. The geographical coordinates are between 38°52'-39°41' north latitude and 109°51'-110°46' east longitude. It is 38-90km long from north to south, 35-55km wide from east to west, and has an area of about 3539km2[2]. Soil salinization is one of the main problems of land degradation in Shendong mining area and threatens the sustainable development of economy and society. As the population continues to increase, underground coal resources are over-exploited and a large amount of drained water generated during the mining process is discharged into the land, resulting in varying degrees of salinization of the land in the mining area, which seriously affects the regional ecological environment. Use desulfurized gypsum, fly ash, sludge and slag mixture to improve the saline-alkali land to achieve "recycling with waste" and "recycling with waste", and large-scale improvement of saline-alkali soil in Shendong mining area Sustainable land use is of great significance.

2. Technical principles

2.1 Desulfurization gypsum

Desulfurization gypsum is a by-product of desulfurization in combustion power plants. Its composition is mainly $CaSO_4 \cdot 2H_2O$[3], which accounts for about 90% of its total composition, has a water content of 6%, and has a pH of about 8.2. It is rich in minerals such as S, Ca, and Si. As the ion substitution performance of Ca^{2+} is higher than that of H^+ and Na^+, the H^+ and Na^+ in saline-alkaline soil can be replaced to reduce the content of H^+ and Na^+ in the soil that is not good for plant growth and increase Ca^+ content; and applying desulfurized gypsum can also reduce the content of HCO^{-3} in the soil and increase the content of water-soluble salt ions in the soil, thereby achieving the effect of improving saline-alkali soil.

2.2 Fly ash

The composition of fly ash is mostly fine vitreous particles with a specific gravity of 2, a bulk density of less than 1, and a small porosity. Fly ash is similar to sandy soil, and about 30% of its particle composition is honeycomb. The color of fly ash is mainly off-white or darker gray[4]. After being applied to the soil, it can significantly improve the soil structure, reduce bulk density, increase porosity, increase ground temperature, and reduce expansion rate, especially for the physical properties of clayey soil There is a good improvement effect. In addition, it can keep heat preservation, promote nutrient conversion, make water, fertilizer, gas, and heat harmonize, and create a good growth environment for crops[5].

2.3 Mixture of sludge and slag

Sludge is rich in organic matter, nitrogen, phosphorus, potassium, copper, zinc, etc. In addition, it also contains a large number of microorganisms. After being added to the soil, it can significantly increase the nutrient elements and microbial biomass in the soil. The application of sludge can increase soil fertility However, due to the viscous nature of the sludge, applying it alone will cause the soil to thicken and reduce soil water permeability, so mixing the sludge and slag can reduce the viscosity of the sludge, and when combined with fly ash, it can increase Large soil porosity improves soil water permeability, thereby achieving the effect of improving saline-alkaline soil[6].

3. Materials and methods

3.1 Test materials

The test soil was taken from the saline-alkali soil improvement test site in the mining area of Daliuta Town, Yulin City, Shaanxi Province. The soil pH was 8.83, which was alkaline soil with low nutrient content. The tested desulfurized gypsum, fly ash, and other solid waste saline-alkali soil improvers were produced by the boiler rooms and sewage treatment plants in the mines of Shendong Mining Area. The tested crop variety was Zhongmu No. 1, plant height 80-100 cm, plant type Upright, with obvious tap root.

3.2 Experimental design

This experiment was conducted in the greenhouse of Inner Mongolia Agricultural University, and the orthogonal experiment $L8(2^3)$ was designed with a 3-factor 2-level experiment design. The treatment level and dosage of each factor are shown in (Table 1 and Table 2), where A represents desulfurized gypsum, B represents fly ash, and C represents the mixture of sludge and slag (the ratio of sludge to slag is 2:1); The planting container is a 300×200mm plastic pot, and each pot contains 1kg of soil in each pot experiment. When the initial soil is potted, different amounts of solid waste modifiers are added in accordance with the settings, fully mixed, and the experiment is started after 3 days of aging. Alfalfa planting management: 5 holes per pot, 6 seeds per hole, 30 seeds/pot in total, 2-4cm in depth.

Table. 1 Coding for each factor

deal with	Factor level		
	A	B	C
CK	0	0	0
S1	1	1	1
S2	1	1	2
S3	1	2	1
S4	1	2	2
S5	2	1	1
S6	2	1	2
S7	2	2	1
S8	2	2	2

Table. 2 Combination of the amount of each processed material

Dosage level	Factors and dosage(g/kg earth)		
	A	B	C
1	15	15	450
2	45	30	900

3.3 Measurement items and measurement methods

Refer to《Methods of Soil Agrochemical Analysis》to determine the basic properties of the substrate, and use Excel software to analyze the test data for data statistics.

4. Experimental results and analysis

4.1 Improvement effect on pH of saline-alkaline soil

Figure 1 shows that each test treatment can lower the pH of the tested soil. According to statistics, the order of the factors that reduce the pH of the tested soil is: A>B>C. Based on the comparison of each group of experiments, Tests 5, 6, 7, and 8 can significantly reduce the pH of the tested soil, while Test 8 is for the tested soil The pH improvement effect is the best. After the treatment of Experiment 8, the soil pH dropped by 0.38 compared with the reference group, which produced a significant improvement effect. This effect can be produced because Ca^{2+} can replace the H^{+} and Na^{+} in the saline-alkali soil. Thereby reducing the salinity of the soil, and the desulfurized gypsum contains a lot of Ca^{2+}.

The mixed application of desulfurized gypsum with fly ash and other solid waste modifiers is more effective than a single application of desulfurized gypsum. Solid waste improvement and combined mixed application significantly reduces the pH value of saline-alkaline soil, promotes the leaching of Na^{+}, and reduces The content of HCO^{-3} in the saline-alkali soil, the pH of the improved test soil was significantly lower than that of the reference group, and the plants planted in the improved soil could grow better.

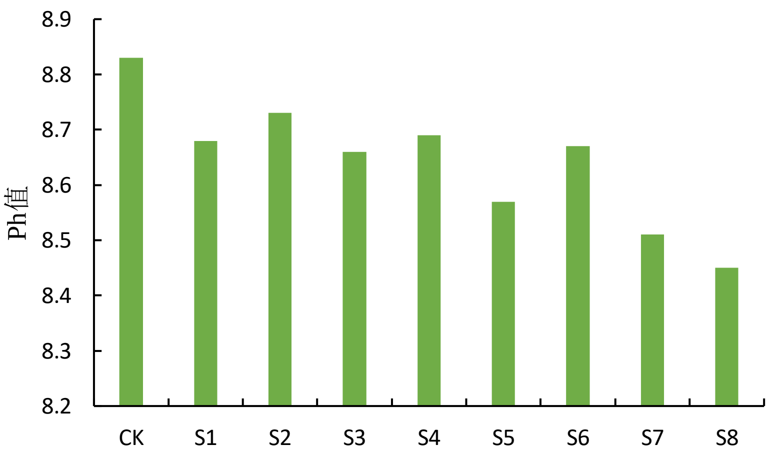

Fig. 1 The pH changes of different treatments in laboratory soil

4.2 Improvement effect on beneficial salt ions of saline-alkaline soil

The type and content of water-soluble salt ions in the soil have a great influence on the growth of plants. As shown in Figure 2, each test treatment significantly increased the beneficial water-soluble salt ions of the soil. According to statistics, the order in which various factors increase soil beneficial water-soluble salt ions is: A>C>B. The salt content of the test after each treatment is greater than the salt content of the reference group, which is related to the addition of solid waste modifiers in the test, especially the addition of desulfurized gypsum will inevitably increase the content of water-soluble salts in the soil water, and the increased total salt Most of them are salt ions that can promote plant growth; Figure 2 shows that the salt content of the first four groups is not much different, and the salt content of the latter four groups is not much different, but the salt content of the latter four groups is significantly different than the first four groups. The main reason for this difference is that the amount of desulfurized gypsum added is different. The amount of desulfurized gypsum added in the first four groups is 1 and the last four groups are 2. The experimental results show that Experiment 8 has the best effect on improving soil content. After the treatment of Experiment 8, the total salt content of the soil increased from 0.44g/kg to 1.35g/kg. Part of the salt in the soil will be lost through watering, but the remaining part will still increase the total salt content in the soil. Although most of the added salt ions are mineral nutrients that are beneficial to plant growth, large areas are improved by applying desulfurized gypsum In saline-alkali land, it is necessary to improve the desulphurized gypsum to the required level to avoid excessive salt content and hinder the normal growth of plants.

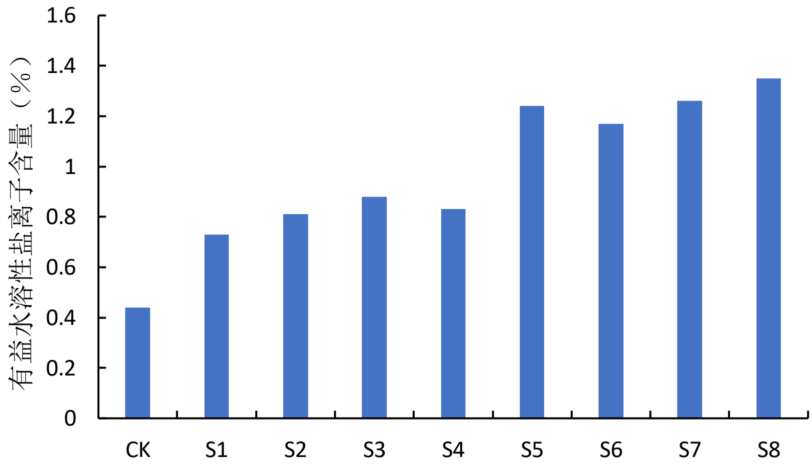

Fig. 2 Variation of total salt content (%) of different treatments in indoor test soil

4.3 Improvement effect on saline-alkali soil SAR

It can be seen from Fig. 3 that compared with the control group, each test treatment significantly reduces the SAR of the soil. The decrease in SAR proves that the Na^{+} content of the experimentally treated soil is decreasing compared with the control group, and the Ca^{2+} content is increasing. This phenomenon is caused by The main component of the desulfurized gypsum applied to the solid waste amendment is $CaSO_4$, which can react with the Na^{+} in the soil to reduce the effect of soil SAR. The amount of desulfurized gypsum added determines the degree of change in soil SAR. The SAR of the last four groups has little difference, and the SAR of the first four groups is not much different, but the SAR of the latter four groups is significantly different from the first four groups.

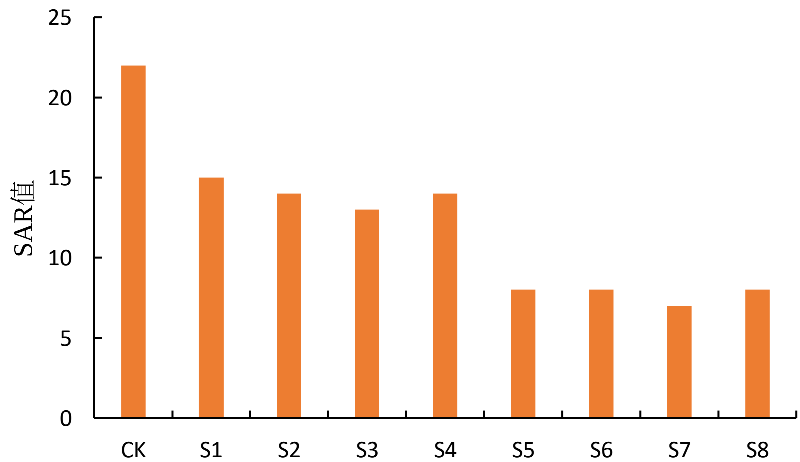

Fig. 3 Variation of SAR in different treatments of indoor experimental soil

4.4 Improvement effect on partial fertility of saline-alkali soil

From Figures 4, 5, 6, 7, 8, 9, and 10, it can be seen that the nutrient index of the test group has significantly improved compared with the control group after each treatment. According to the statistical results, the order of the factors that affect the soil nutrient content As: C>A>B, each test group significantly increased the nutrient content of the soil compared with the control group, and produced a significant improvement effect. This effect is due to the application of solid waste amendments, especially the addition of pollutants. Mud will inevitably increase the nutrient content of the soil. The sludge contains a large amount of N, P, K, and organic matter, which can provide rich fertility for the soil; the figure shows that there is no significant difference in the nutrient content in experiments 1, 3, 5, and 7. There is no significant difference in nutrient content in experiments 2, 4, 6, and 8, which is mainly related to the amount of sludge. In experiments 1, 3, 5, and 7, the sludge dosage level is 1, while in experiments 2, 4, 6, and 8. The dosage level of medium sludge is 2, because the improvement effect produced by the application amount of sludge is also regular differences. Among them, Experiment 8 had the most significant effect on the increase of soil nutrient content.

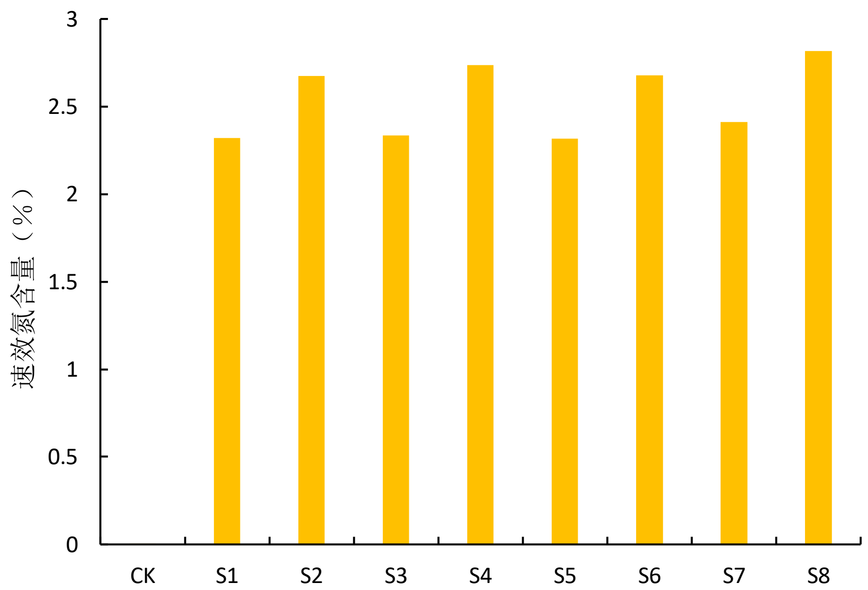

Fig. 4 Changes of available nitrogen (%) in different treatments in laboratory soil

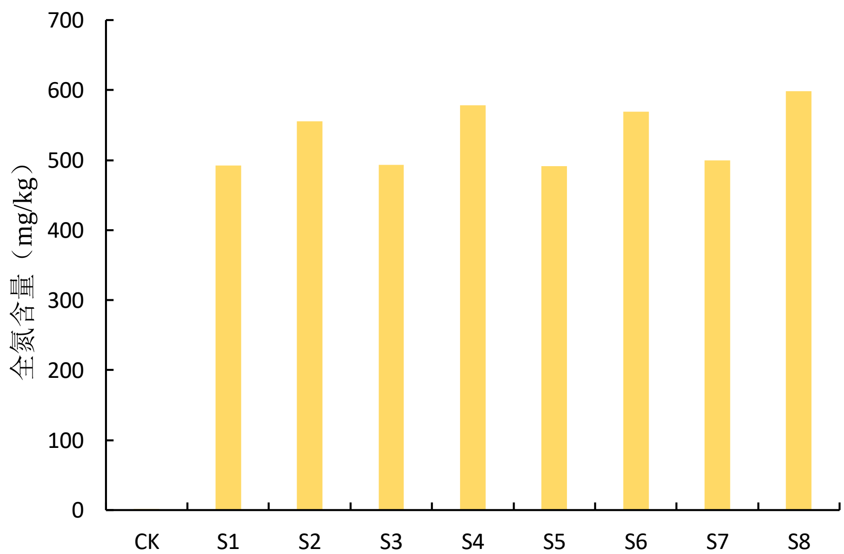

Fig. 5 The change of total nitrogen (mg/kg) in different treatments of indoor test soil

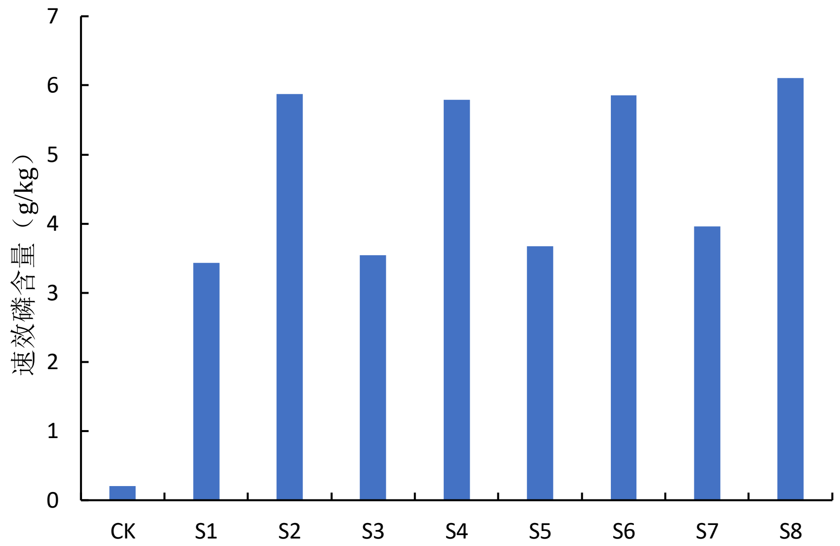

Fig. 6 Indoor test soil available phosphorus (g/kg) changes in different treatments

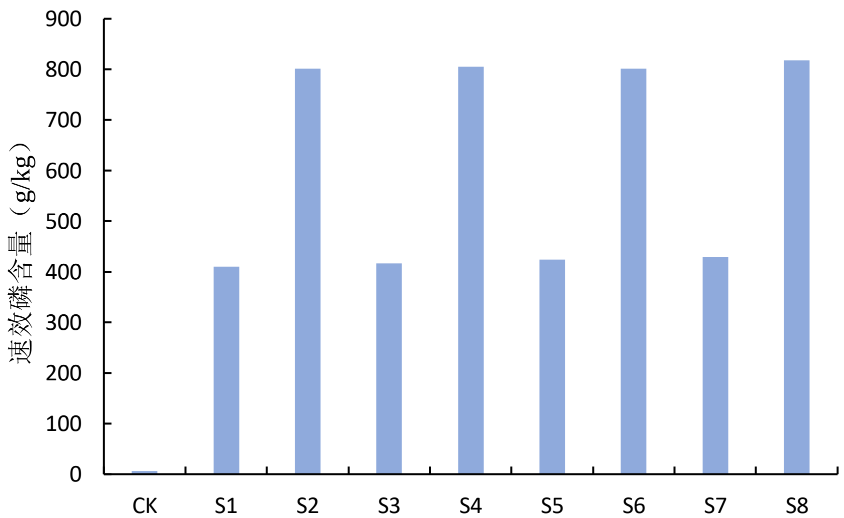

Fig. 7 The change of total phosphorus (mg/kg) in different treatments of indoor test soil

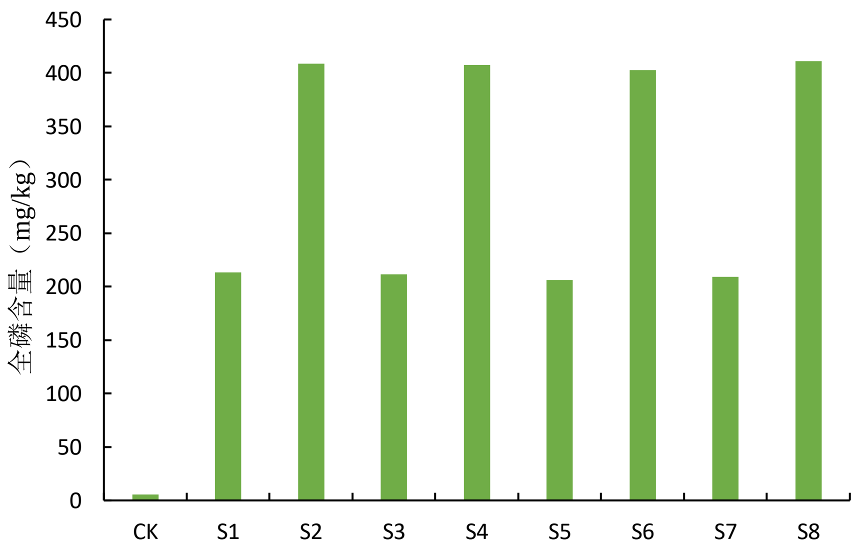

Fig. 8 Indoor test soil available potassium (g/kg) change under different treatments

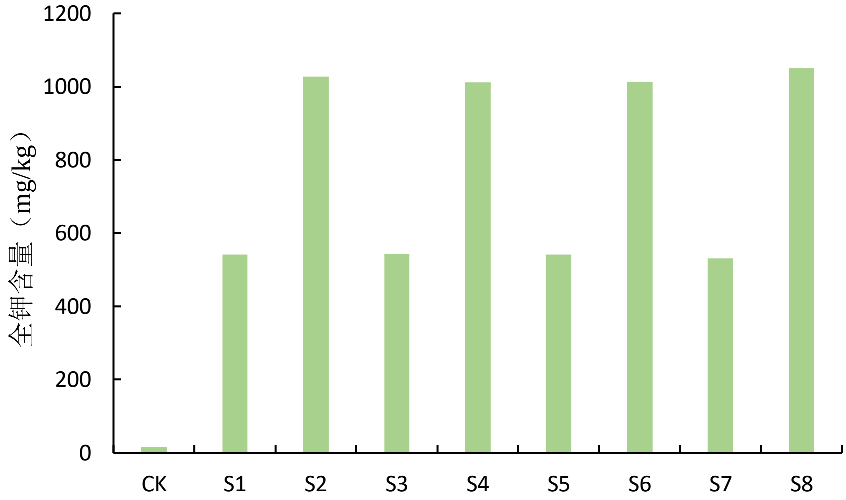

Fig. 9 The change of total potassium (mg/kg) in different treatments of indoor test soil

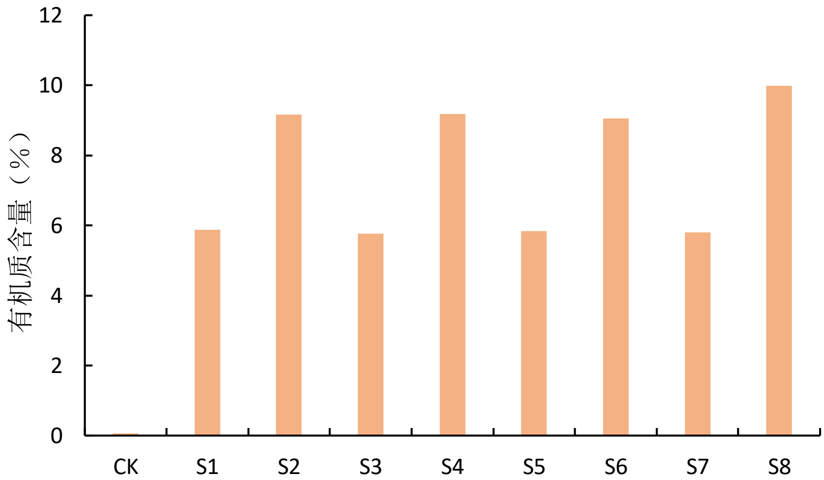

Fig. 10 Indoor test soil organic matter (%) changes in different treatments

4.5 Impact on the growth of alfalfa

It can be seen from Table 3 that the application of solid waste modifier can significantly increase the emergence rate of alfalfa, but the emergence rate of alfalfa does not increase with the increase in the application rate. The overall performance is Test 6> Test 2> Test 4> Test 8> Test 7 > Test 5> Test 1> Test 3> Control. Test 6 has the highest emergence rate, which is 31% higher than the control. The changing trends of alfalfa plant height, water content, and dry matter are consistent, and they are all shown as test 2>test 6>test 8>test 4>test 1>test 5>test 7>test 3>control, test 2 water content, dry matter quality The equal value is the largest, 20.4% and 98.6% higher than the control. The application of solid waste improver can affect the number of tillers of alfalfa. The number of tillers of alfalfa applied is generally higher than that of the control, which is as follows: Test 2> Test 8> Test 6> Test 4> Test 5> Test 1> Test 7> Test 3> Control: Treatment 2 had the largest number of tillers, with an average of 2.98, an increase of 68% compared to the control. The analysis suggests that the application of desulphurized gypsum, fly ash and other solid wastes changed the soil structure, in which Ca^{2+} replaced the N^{+} on the soil colloid, reduced the N^{+} content on the soil colloid, reduced the soil alkalinity, and improved the soil Permeability enables alfalfa to grow in a good soil environment, promotes seed germination and plant growth, and is beneficial to increase the emergence rate of alfalfa and increase the number of tillers. In addition, the applied sludge is rich in N, P, K, organic matter and other essential or beneficial nutrient indicators for plants, and has a high water content, which plays a certain role in increasing the nutrients and water required by alfalfa.

Table. 3 Measurement results of alfalfa related growth indicators

project	Control	S1	S2	S3	S4	S5	S6	S7	S8
Emergence rate/%	61.73	68.19	85.44	67.59	85.12	70.09	89.38	74.28	83.92
Average plant height/cm	15.18	19.47	23.79	16.74	21.39	19.14	22.28	16.89	22.14
Water content/%	69.28	72.49	83.45	69.99	82.47	72.08	83.18	72.03	82.95
Dry biomass/g	6.49	9.37	12.89	7.94	11.96	9.27	12.41	0.14	12.09
Divided number/A	1.77	1.88	2.98	1.81	2.07	1.95	2.86	1.83	2.49

5. Conclusion and discussion

(1) Through the analysis of the physical and chemical properties of desulfurized gypsum in the solid waste improver used in improving saline-alkali land in mining areas, it can be seen that the improved saline-alkali land by desulfurization gypsum is mainly based on its chemical properties. The main component of desulfurized gypsum is $CaSO_4$ and contains impurities such as $CaCO_3$. The ion substitution performance of Ca^{2+} is higher than that of H^+ and Na^+, so H^+ and Na^+ in saline-alkali soil can be replaced to reduce the content of H^+ and Na^+ in the soil that is not good for plant growth and increase the content of Ca^+ that is good for plant growth; The application of desulfurized gypsum can also reduce the content of HCO^{-3} in the soil and increase the content of water-soluble salt ions in the soil, thereby achieving the effect of improving saline-alkali soil. Although the content of desulfurized gypsum is not as high as that of pure gypsum, it has the same performance and effect as pure gypsum. The advantage of desulfurized gypsum over pure gypsum is that desulfurized gypsum is an industrial solid waste, and the cost for improving saline-alkali land is lower, and the use of desulfurized gypsum to improve saline-alkali land can realize waste recycling. These characteristics make desulfurized gypsum more advantageous in the improvement of saline-alkali land.

(2) Through the analysis of the physical and chemical properties of fly ash in the solid waste improver used to improve the saline-alkali land in the mining area, it can be seen that the improved saline-alkali land with fly ash is mainly based on its physical properties. The main physical properties of fly ash are fly ash, salt After the application of fly ash, the compactness of the alkaline soil decreases and the total porosity increases. The main manifestation is that the content of micro-aggregates and the degree of agglomeration of >50μm increase, and the water permeability of the saline-alkali soil becomes better, so as to achieve the improved effect. Fly ash is industrial solid waste, and the application of fly ash to improve saline-alkali land can realize waste recycling.

(3) Through the analysis of the physicochemical properties of sludge and slag in the solid waste modifier used in improving the saline-alkali land in the mining area, it can be seen that the improvement of the saline-alkali land with fly ash is mainly based on the rich nutrients in the sludge, and the application of sludge can increase soil fertility However, due to the viscous nature of the sludge, applying it alone will cause the soil to thicken and reduce soil water permeability. Therefore, mixing the sludge and slag can reduce the viscosity of the sludge, and mix with fly ash to increase Large soil porosity improves soil water permeability, thereby achieving the effect of improving saline-alkaline soil. In summary, in the process of improvement, a mixture of desulfurized gypsum and fly ash, sludge and slag can be used to achieve a more comprehensive effect.

(4) From the results of the pot experiment, it can be seen from the chemical properties that the content of Ph, SAR and other ions that are not conducive to plant growth in the soil after being improved by the solid waste amendment is significantly lower than that of the unimproved soil. It is beneficial to water-soluble salt ions, Fertility and other ions that are conducive to plant growth have been significantly increased; from the point of view of physical properties, the soil is improved by solid waste amendments, and the compactness of the soil is reduced compared with the unimproved soil, the total porosity is increased, and the water permeability of saline-alkali soil becomes more Well, combining these two points, it can be seen that it is feasible to use the mixture of desulfurized gypsum and fly ash, sludge and slag to improve saline-alkali land.

This study is aimed at the saline-alkali soil of Shendong. The application of desulfurized gypsum and fly ash, and the mixture of sludge and slag to improve saline-alkali soil has significant effects. Although many researchers have focused on improving saline-alkali soil with desulfurized gypsum and fly ash. A lot of research has been done, but the research on improving the saline-alkali land with the mixture of desulfurized gypsum and fly ash and sludge and slag is still slightly insufficient, especially the improvement of the saline-alkali land in mining areas. Therefore, the viewpoints established in this study, the experiments carried out and the conclusions obtained are critical to the theoretical support and practical application of the combination of desulfurized gypsum and fly ash, and the mixture of sludge and slag to improve saline-alkali soils, especially saline-alkali soils in mining areas.

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