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EFFECTS OF DIFFERENT SOIL AMENDMENTS ON SOIL PHYSICAL AND CHEMICAL PROPERTIES AND OIL SUNFLOWER YIELD IN SALINE-SODIC IN NORTHERN SHAANXI CHINA

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Keywords: Soil Amendment, Desulfurized Gypsum, Microbial Agent, Physical and Chemical properties of soil, Oil sunflower, Yield

Abstract

In order to explore the response effects of different amendments and salt tolerant crops on the management of moderate saline-sodic and crop yield, this study was carried out in typical saline-sodic in Northern Shaanxi. Taking the salt tolerant crop oil sunflower as the research object, three soil amendments were applied, including desulfurization gypsum (FGD), "xiyoufeng" soil amendment (SA) and "yueyuyuan" microbial agent (MA). The effects of different amendments on soil physical and chemical properties and oil sunflower yield were analyzed. The results showed that the application of soil additives effectively reduced the soil pH, total salt content and bulk density of saline-sodic by 2.24~10.15, 0.82~15.76 and 2.67%~8.00%; the soil organic matter, hydrolyzable nitrogen, available phosphorus and available potassium were increased respectively by 15.65~56.55, 2.32~39.57, 49.75~95.48 and 5.33%~32.96%; the plant height and stem diameter of oil sunflower were increased respectively by 1.50~9.02%, 0.84~4.20%; the yield was increased by 17.67~72.24%, and the quality was improved. Compared with CK, soil pH, total salt content and bulk density decreased by 0.91, 0.12 g/kg and 0.84 g/cm^3, respectively, and the yield increased by 1153.37 kg/hm^{-2}, which provided a practical reference scheme for the improvement of saline-sodic in arid areas. It was suggested that YUEYUYUAN microbial agent should be preferred to treat moderate saline-sodic in Northern Shaanxi. Our study provides scientific recommendations for applying amendments worldwide in the saline-sodic.

Introduction

Soil salinization has been regarded as a critical issue that poses a significant threat to global food security (Sahab *et al*. 2021). The high content of salt and alkali in soil has many adverse effects on vegetation growth, agricultural production, and ecological environment (Yang 2018). According to the third land survey, the area of saline-sodic was about 7.67 × 10^6 hm^2, with 45.4% of saline soil, 2.5% of alkaline soil, and 52.1% of saline and alkali soil in China (Yang 2018). Due to the arid climate, scarce rainfall, sufficient sunshine, semi-arid regions with high evaporation, low precipitation, and special topography in the Northwest of China. The saline-sodic in this region was known as the "World Museum of saline-sodic", accounting for 69.03% of the country. At present, The area of saline-sodic in Shaanxi Province was about 21.30 × 10^4 hm^2, which was mainly distributed in Yulin area in Northern Shaanxi and Weinan area in Guanzhong. The heavy and moderate saline-sodic was about 1.60 × 10^5 hm^2, and increasing. The degree of salinization was becoming increasingly severe (Pang *et al*. 2023,Wang *et al.* 2023).

After years of exploration and practice, the measures of saline-sodic have formed three major paths of "suitable planting for land", "suitable planting for land", and "suitable planting for land", as well as four measures of physical measures, chemical measures, biological measures, and comprehensive measures. There were Physical treatment measures (covering sand and soil, micro

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area soil improvement, deep plowing and deep plowing, ground covering, etc.), Chemical improvement measures (phosphogypsum, humic acid, superphosphate, slag, etc.), Biological treatment measures (salt alkali tolerant crops, microbial nano integration technology, green manure, etc.), Comprehensive treatment measures (Engineering + Chemical + Desalination water-saving, Engineering + Biology + Agriculture, Deep plowing + Application of Chemical amendments + Planting of salt alkali tolerant plants, etc.). Differentiated approaches were required for managing saline-alkali soil across various regions and degrees of salinity. Consequently, identifying locally appropriate and feasible methods for saline-alkali soil remediation, enhancing the soil environment of the arable layer, mitigating the adverse effects of soil salinization, and boosting crop yields have emerged as pivotal scientific challenges in enhancing the quality of cultivated land in China.

Soil amendments represented a novel product designed for the management of saline-alkali soil, aligned with the industrial development of the new era. They exhibit pronounced treatment effects within a relatively short period, commonly featuring reduced soil bulk density, enhanced soil water and fertilizer retention capabilities, and accelerated crop growth (Chen *et al.* 2024, Jiang *et al.* 2024). As for the effects on soil amendments, the representative literature is as follows. Wu *et al*. (2021) found that soil amendments can enhance soil physicochemical properties to different extents and boost rice yield and production value. Yang (2025) found that the application of microbial agents can reduce soil pH and decrease the total amount of water-soluble salts effectively in the soil. In addition, microbial agents can improve soil nutrients and microbial community structure, further increasing crop yield and quality (Li *et al*. 2024). Zhou (2016) found that desulfurization gypsum and humic acid can reduce soil pH and salt content, and increase soil organic matter, total nitrogen, and available potassium content significantly. The application of soil amendments can enhance the thousand-grain weight and yield of rice markedly. In addition, cultivating salt-tolerant crops can enhance soil structure and boost soil microbial activity, representing one of the most economically viable improvement measures for the management of saline-alkali soil (Yang *et al.* 2008). Oil sunflower was a common salt tolerant crop in northern China (Ma *et al.* 2024). Hao *et al.* (2019) developed a comprehensive technology model for improving saline-alkali soil to cultivate oil sunflowers, incorporating "organic fertilizer, trenching and ridging, sand mulching, desulfurized gypsum application, and plastic mulching," which boosted significantly the yield of oil sunflowers. Liang *et al.* (2024) found that the application of various soil amendments can significantly enhance oil sunflower growth, increasing aboveground dry matter accumulation by 16.18% and improving yield by 13.80%.

Although previous studies have explored the use of various soil amendments and the cultivation of salt-tolerant crops, systematic research on the optimal integration of amendment properties with crop cultivation practices remains limited. The study conducted field experiments in Dingbian County, Yulin City, to investigate the effects of different soil amendments on the physicochemical properties of saline-alkali soil and the yield of oil sunflower. The objective was to optimize soil conditioning and nutrient management strategies for oil sunflower cultivation in northern Shaanxi's typical saline-alkali lands. The study aims to support large-scale oil sunflower production, and enhance arable land quality in the region, and provide innovative technical approaches and theoretical guidance for sustainable saline-alkali soil remediation.

Material and Methods

The experiment was conducted from May to October 2024 in Wangtanzi Village, Duiziliang Town, Dingbian County, Yulin City, Shaanxi Province (geographical coordinates were E 108°15′00"~108°18′45", N 37°37′30"~37°42′30"), as shown in Fig. 1. The experimental area was in the transitional zone between the Maowusu Desert and the Loess Plateau, with shallow groundwater level and poor drainage conditions. Strong evaporation promotes the migration and enrichment of salt with capillary water to the surface, forming a significant accumulation of salt and exhibiting typical characteristics of saline soil. The climate in this region belongs to the temperate continental semi-arid monsoon climate. In 2024, the sunshine hours were 2830 hrs, with the most abundant sunshine from May to August (with an average of 240-260 hrs per month) and a precipitation of 344 mm. The rainfall was mainly concentrated from July to September each year, the precipitation was 138.1 mm in the oil sunflower growth period. The soil type was loam soil, and the soil bulk density was 1.55 g/cm^3, the soil pH was 9.46, and the total water-soluble salt content was 5.4 g/kg from 0 to 30 cm before sowing. It belongs to moderate saline-sodic, and the irrigation water source was -80 m groundwater. The various indicators of irrigation water were shown in Table 1.

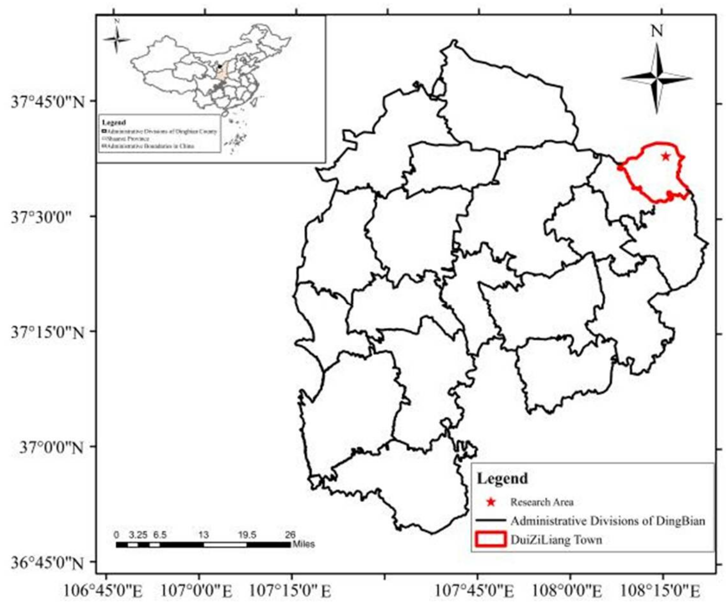

Fig.1. The Geographic sketch maps of experiment.

Table 1. The various indicators of irrigation water.

Indicators	pH	Total Salt content mg/l	Stiffness mg/l	Salinity mg/l	Potassium mg/l	Sodium mg/l	Calcium mg/l
number	8.45	291.67	243	291.68	2.64	19.12	27.16

The desulfurization gypsum was provided by Ningxia Chuangjia Environmental Technology Co. Ltd, and the $CaSO_4$ and H_2O was equal or greater than 93%, moisture content ≤ 10%, density was 2.3 g/cm^3, pH was 8.3, and the dosage was 20000 kg/hm^2. The "Xiyoufeng" soil amendment was developed by Beijing Zhonggeng Oasis Ecological Technology Co. Ltd. and produced by Tongliao Zhonggeng Green Soil Biotechnology Co. Ltd. The organic matter content was equal or greater than 40%, and the organic material sources were primarily agricultural waste, livestock manure, green manure, etc., and the decomposition state refers to the degree of maturity. The effective viable bacterial count was equal or greater than 20 million/ml, and the microbial types are bacteria, fungi, and archaea, accounting for 40, 40, and 20% respectively. The pH after water solubility was 5.7, and the dosage was 15000 kg/hm^2, The "Yueyuyuan" microbial agent was produced by Inner Mongolia Dongyuan Langsen Ecological Technology Company, with an effective live bacterial count was equal or greater than 500 million/ml, and the microbial types are bacteria, fungi, and archaea, accounting for 40, 35 and 25%, respectively. The total nutrient N + P_2O_5 + K_2O was equal or greater than 6.0%, free amino acids were equal or greater than 30 g/ml, organic matter was equal or greater than 100 g/ml, and the organic matter is readily biodegradable, water-soluble pH was 3.4, and the dosage was 15000 kg/hm^2. The dosage of the improver should be adjusted moderately according to the manufacturer's recommended dosage. The variety of oil sunflower was short and large head. It was sown mechanically in June 2024 early, with about 2-3 seeds per hole, weighing 7.5-8.0 kg/hm^2. It matured and harvested in October late. The distance between oil sunflower plants was 30 cm, and the distance between rows was 60 cm. Each row of oil sunflower was equipped with a separate drip irrigation belt, and the distance between the drip irrigation belt and the oil sunflower was 3 cm, as shown in Fig. 2.

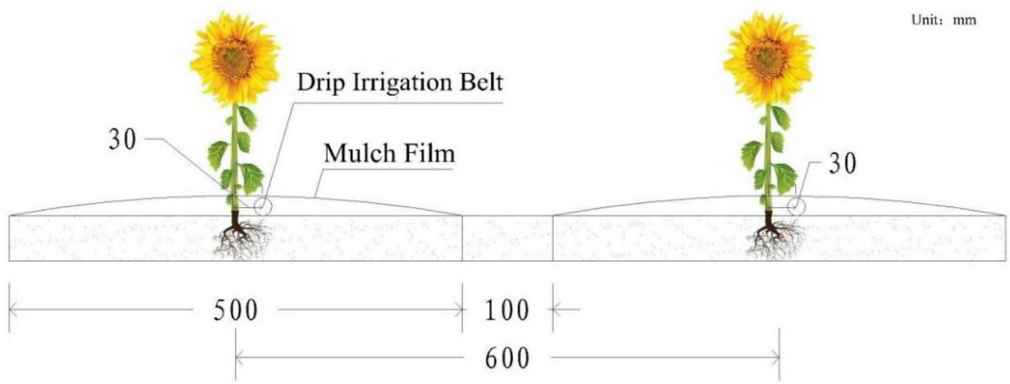

Fig. 2. The mode of planting Oil sunflower.

According to three different soil amendments, the experiment was adopted orthogonal test of a three-factor one-level and a total of four treatments were set up in the experiment, it included no application (CK), application of desulfurized gypsum (FGD), application of “XIYOUFENG” soil amendment (SA), and application of “YUEYUYUAN” microbial agent (MA). Three replicates were set for each treatment. The test plot area of treatment was 1.21 hm^2 (110m × 110 m), and each treatment was about 0.1 hm^2. And in order to prevent the interaction between various treatments, the interval of 2 m was set between the treatments, and the surrounding area was ridged and covered with plastic film. Isolation measures were strictly taken between the treatments. The submersible pump in the motor well was used to extract groundwater for irrigation. A water meter was installed at the head, and a three-level filtered fertilization irrigation was set up with a capacity of 500 L. The main irrigation pipe and embedded patch drip irrigation belt were arranged in the field. The main pipe was black PE pipe with a diameter of 90 mm. Each row of sunflower was arranged with a drip irrigation belt, with a spacing of 30 cm and a flow rate of 3 l/h. The rotary valve was installed on the drip irrigation belt at the connection between each drip irrigation belt and the main pipe. On April 25, 2024, cow dung mixed with biological bacteria was applied to the plot, which fermented for 30 days at the dosage of 45 t/hm^2. On June 1, fermented cow dung was applied and tilled, on June 5, soil conditioner was applied and rotary tilled, and on June 10, mechanical hole sowing was used, and the sowing depth was 3~4cm.

According to the local planting habits, the whole growth period of oil sunflower was irrigated three times, including one time of keeping seedling water, the irrigation quota was 300 m^3/hm^2, one time of irrigation in budding period and one time of irrigation in flowering period, the irrigation quota was 600 m^3/hm^2, the date of keeping seedling water irrigation was June 22, the date of irrigation in budding period and flowering period were July 25 and August 27, respectively, and the topdressing fertilizer (urea (n ≥ 46%) and potassium fertilizer (K_2O ≥ 60%) were dissolved in water through fertilization irrigation, and then applied with water through drip irrigation. In order to reduce soil water evaporation and nutrient consumption, intertillage and timely field management were carried out according to the actual situation. The physical and chemical properties of soil samples before planting in Table 2. and the irrigation quota, application amount of soil conditioner and fertilization amount in Table 3.

Table 2. The physical and chemical properties of soil samples before planting.

Indicators	pH	Total water-soluble salt g/kg	Organic matter g/kg	Mineral nitrogen mg/kg	Olsen-P mg/kg	Available K mg/kg	Clay %	Silt %	Sand %
number	9.46	5.40	4.53	38.90	17.00	210.00	2.39	54.64	42.97

Table 3. The irrigation quota, application amount of soil conditioner and fertilization amount.

Unit	Soil Amendment	Amount of Soil Amendment	Irrigation Quota/ m^3 hm^2	Type and amount of fertilization/ kg·hm^2	
				Urea	Potash fertilizer
FGD	Desulfurized Gypsum	20000	1500	450	150
SA	XIYOUFENG	15000	1500	450	150
MA	YUEYUYUAN	15000	1500	450	150
CK	-	-	1500	450	150

Ten oil sunflower plants with the same growth status were randomly selected and marked in each unit, and 30 plants were selected for each treatment. The plant height was measured vertically from the stem base to the growth point with a 5m tape, and the stem diameter was measured 2cm above the cotyledon node with an electronic digital caliper with an accuracy of 0.02 mm. The measurement was recorded every 7 days.

At the harvest stage of the experimental field, three sampling points were randomly arranged according to the "S" shaped route, and the oil sunflower samples with the same growth status and representative of the overall population were selected. Ten standard plants (plant height ± 5% range, and no pests and diseases) were selected at each sampling point. After manual harvesting, the diameter of the disc was measured, and the threshing was completed within 48 hrs. The dry in the shade method (25°C ventilation and dark protection) was used to constant weight, and the weight of 100 seeds was measured. Then the samples from three sampling points were mixed into one sample for seed test, and the grain yield of each treatment unit was calculated and converted into the actual yield.

After standardized screening of oil sunflower seeds, complete seeds with uniform particle size and maturity standard were selected for quality analysis, and crude fat, crude protein, oleic acid, linoleic acid, linolenic acid and other indicators were determined according to ISO 659 and ISO 20483 and ISO 12966.

Due to the narrow width of each unit, the serpentine method was used to sample 0-30 cm soil layer before sowing and after harvest with the quartering method and sent to the detection institution to determine the soil pH, total water-soluble salt, organic matter, Mineral nitrogen, available phosphorus, available potassium, etc. The specific method was: soil pH, The determination of soil pH was commonly carried out by the potentiometric method, as specified in the international standard ISO 10390; The total water-soluble salts were determined by measuring the electrical conductivity of a soil saturation extract obtained following the international standard ISO 11265. The organic matter content was determined according to ISO 14235 standard by oxidizing organic carbon with potassium dichromate-sulfuric solution under heating conditions. The organic carbon content is calculated by titrating the remaining potassium dichromate, and then multiplied by a conversion factor (typically 1.724) to obtain the organic matter content. The mineral N was extracted using a 2M KCl solution in accordance with ISO 14256 and subsequently determined by spectrophotometric methods. The available phosphorus was extracted and determined using a sodium bicarbonate solution following international standard methods. The Available potassium was extracted using a 1 M neutral ammonium acetate solution according to international standard methods, followed by determination using flame photometry or atomic absorption spectrometry.

Soil bulk density was determined using the core cutter method with 0~30cm undisturbed soil samples in accordance with ISO 11272. Particle size distribution was analyzed in accordance with ISO 11277 international standard through a combination of sieving and sedimentation (pipette) to determine the relative proportions of sand, silt, and clay in soil.

PS office and Origin2021 were used for statistics, analysis of variance, significance test ($p < 0.05$) and drawing of test data.

Results and Discussion

Soil pH was the core of soil chemical index, which directly reflects the degree of soil acidity and alkalinity and affected the enzyme activity of microorganisms in the soil. When it exceeded the appropriate critical threshold for crops, it was not conducive to the absorption of effective nutrients by plant roots. It can be seen from Fig. 3 that different treatments have significantly

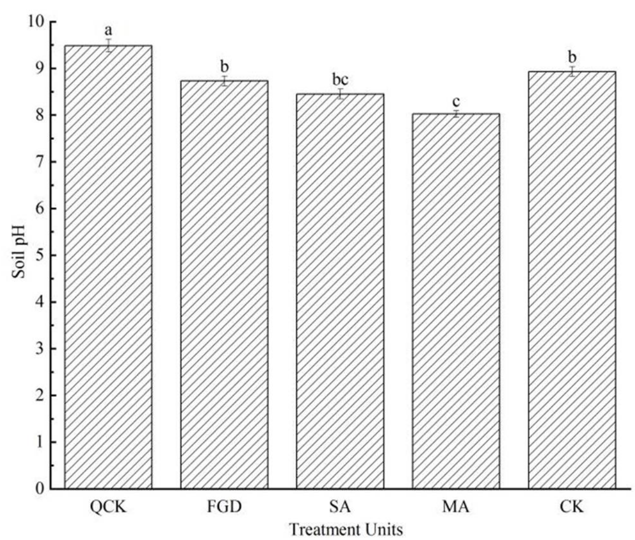

Fig. 3. The effects of different treatments on soil pH in saline-sodic. Different letters in the same row indicate significant differences ($p < 0.05\%$) among different treatments (Data processing system Origin 2021).

reduced soil bulk density and pH. Before sowing, the soil pH was 9.46. After harvest, the pH of CK treatment was the highest, which was 8.93, affected the normal growth of oil sunflower. Compared with before harvest (QCK), CK, MA, SA, FGD decreased respectively by 0.53, 1.46, 1.04, 0.77. Compared with CK, MA, SA, FGD decreased respectively by 0.91, 0.48, 0.20. Both "YUEYUYUAN" microbial agent and "XIYOUFENG" soil conditioner were acidic, and they reduced soil pH by the chemical reaction of neutralizing between acid and alkali; The main components of Desulfurization gypsum reduced soil pH because the Ca^{2+} in desulfurization gypsum reacted with free CO_3^- and CO_3^{2-} in soil to form insoluble $CaCO_3$ or Ca $(HCO_3)_2$, and the main components of Desulfurization gypsum were $CaSO_4$ and a small amount of $CaSO_3$.

The structure of soil was an important physical property that directly reflected the factors such as water, fertilizer, air, and heat in soil. The three-phase structure (clay, silt, and sand) and bulk density of soil were physical indicators that reflected soil structure. The soil amendments significantly reduced soil bulk density, and increased soil internal porosity and improved soil physical properties in Table 4. Compared with that before sowing and after harvest, the soil bulk density, clay, and silt decreased and the sand content increased after harvest, because the destruction of soil aggregates caused by cultivation. On the other hand, organic matter, as the cementation agent of soil aggregates, the reduction of soil organic matter content because the absorption of nutrients of crops, further weakening the stability of aggregates, and dispersion and loss of clay and silt. Compared with the CK, the soil bulk density, clay and sand were significantly reduced, and the soil silt was significantly increased in each treatment. The improvement effect of MA on soil physical properties was the best, followed by SA, and FGD was the worst. The soil bulk density of MA, SA, and FGD treatments were significantly reduced respectively by 0.12, 0.09, and 0.04 g/cm^3, the soil clay was significantly reduced by 0.20, 0.13, and 0.06%, the soil sand was reduced by 1.02, 0.42, and 0.20%, and the soil silt was increased by 1.22, 0.55, and 0.26%.

The application of soil amendments increased soil porosity, improve soil physical properties, effectively improve soil aeration, and enhance the water retention capacity and nutrient supply capacity of soil surface, which was conducive to the growth of oil sunflower.

Table 4. The effects of different treatments on physical properties of saline-sodic.

Units	Soil bulk density g/cm^3	Clay (%)	Silt (%)	Sand (%)
QCK	1.55 ± 0.02a	2.4 ± 0.08a	54.61 ± 0.25b	42.99 ± 0.26ab
FGD	1.46 ± 0.06ab	2.29 ± 0.08ab	54.8 ± 0.25b	42.91 ± 0.07ab
SA	1.41 ± 0.02b	2.22 ± 0.12ab	55.09 ± 0.5ab	42.69 ± 0.26b
MA	1.38 ± 0.06b	2.15 ± 0.04b	55.76 ± 0.38a	42.09 ± 0.13c
CK	1.5 ± 0.06ab	2.35 ± 0.08ab	54.54 ± 0.13b	43.11 ± 0.07a

Different letters in the same row indicate significant differences ($p < 0.05\%$) among different treatments (Data processing system Origin2021).

The content of salt in soil was an important indicator of soil salinization, which directly affected the normal growth and development of crops. Different treatments significantly reduced the total salt content of soil in Fig. 4. The total salt content of soil before sowing was 5.42 g/kg. After harvest, the total salt content of CK treatment was the highest, which was 5.30 g/kg. Compared with that before harvest, CK, MA, SA, FGD were reduced by 0.12, 0.96, 0.51, 0.16 g/kg compared with QCK, MA, SA, FGD were reduced by 0.84, 0.39, 0.04 g/kg compared with the CK. Which reduced the total salt content of soil by enhancing the adsorption and fixation of

Cl^-, SO_4^{2-} and other anions in soil colloid through exchange reaction of Na^+, Ca^{2+}; In addition, which prevented upward migration of salt by promoting the formation of soil aggregates and destroying capillary pores the modifier promoted the formation of water stable aggregates through optimized the proportion of soil three-phase structure and determined water stable aggregates greater than 0.25 mm.The comparison before and after planting oil sunflower shows that planting oil sunflower reduced significantly the total salt content in the soil surface, salt tolerant crops play their biological desalination function, absorb the salt content in the soil, and reduced the surface evaporation after planting oil sunflower, inhibit the upward migration of salt with water, so the salt content in the soil surface was significantly reduced.

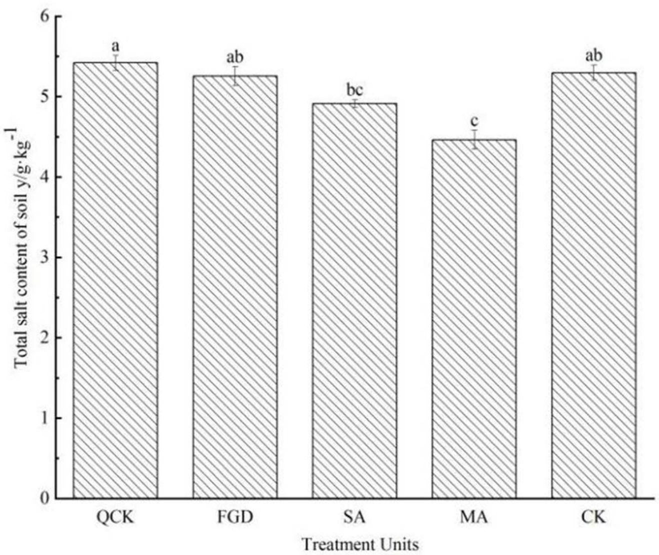

Fig. 4. The Effects of different treatments on total salt content of saline-sodic. Different letters in the same row indicatesignificant differences ($p < 0.05\%$) among different treatments (Data processing system Origin 2021).

Soil nutrients were the basic material supply system for plant growth (Li *et al*. 2024), and the core elements include organic matter and mineral nutrients (nitrogen, phosphorus, potassium, calcium, iron, etc.), and the organic matter was the carrier of nutrient storage capacity. It can be seen from Table 5 that, compared with before sowing, which reduced the organic matter in soil because that required a large amount of organic matter in the growth of oil sunflower, and amendments and fertilization increased the contents of soil hydrolytic nitrogen, available phosphorus and available potassium (Yang *et al*. 2008). Compared with CK, the contents of soil organic matter, hydrolyzable nitrogen, available phosphorus and available potassium in different treatments were significantly increased, and MA was the highest, which was 4.90 g/kg, 54.71 mg/kg, 35.48 mg/kg and 294.29 mg/kg, while CK was the lowest, which was 3.13 g/kg, 39.20 mg/kg, 18.15 mg/kg and 221.34 mg/kg, indicating that "YUEYUYUAN" microbial agent had the most significant effect on the increase of soil nutrient content, followed by "XIYOUFENG" soil modifier, and then desulfurization. The average value of gypsum and organic matter increased by 1.77, 0.90 and 0.49 g/kg, the average value of hydrolyzable nitrogen increased by 15.51, 1.20 and 0.91 mg/kg, the average value of available phosphorus increased by 17.33, 12.72 and 9.03 mg/kg, and the average value of available potassium increased by 72.95, 35.53 and 11.80 mg/kg.

Table 5. The Effects of different treatments on soil nutrients in saline-sodic.

Units	Organic matter (g/kg)	Mineral nitrogen (mg/kg)	Olsen-P (mg/kg)	Available K (mg/kg)
QCK	3.55 ± 0.09c	38.94 ± 0.93b	17.01 ± 0.27d	212.25 ± 17.94c
FGD	3.62 ± 0.05c	40.11 ± 0.74b	27.18 ± 0.68c	233.15 ± 12.82bc
SA	4.03 ± 0.06b	40.40 ± 0.93b	30.87 ± 0.68b	256.87 ± 7.69b
MA	4.90 ± 0.06a	54.71 ± 0.93a	35.48 ± 0.81a	294.29 ± 10.25a
CK	3.13 ± 0.05d	39.20 ± 0.74b	18.15 ± 0.81d	221.34 ± 5.13c

Different letters in the same row indicate significant differences ($p < 0.05\%$) among different treatments (Data processing system Origin2021).

The dynamic changes of plant height of oil sunflower under different treatment conditions were rapid growth period (seedling stage-budding stage), slow growth period (budding stage-flowering stage), physiological maturity period (flowering stage-after maturity stage) in Fig. 5. The flowering stage was selected for the significance analysis of plant height of oil sunflower ($p < 0.05$) because the plant height reached the biological maximum at flowering stage. The order of plant height of oil sunflower in different treatments was from large to small was MA > SA > FGD > CK. The plant height of MA, SA, FGD increased 12.00 cm, 7.99 cm and 2.00 cm compared with CK; The stem diameter and plant height of oil sunflower were basically the same under different treatment conditions, but the stem diameter reached the maximum at the mature stage. The significance of stem diameter of oil sunflower was analyzed by taking the mature stage as an example. The order of stem diameter of oil sunflower in different treatments was from large to small was MA > SA > FGD > CK, and it increased respectively by 0.15 cm, 0.09 cm and 0.03 cm, compared with CK.

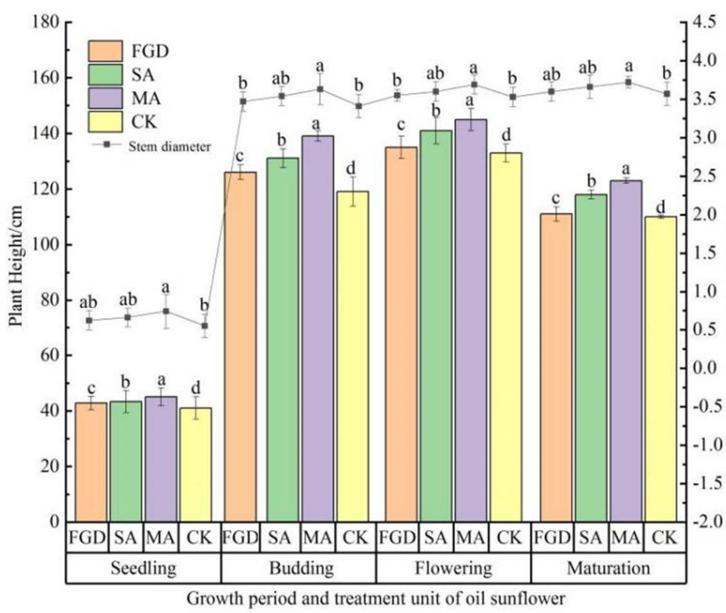

Fig. 5. Effects of different treatments on plant height and stem diameter of oil sunflower. Different letters in the same row indicate significant differences ($p < 0.05\%$) among different treatments (Data processing system Origin 2021).

Overall, the growth performance index of oil sunflower with "YUEYUYUAN" microbial agent was the best. Because the soil in this area was alkaline (the soil pH was 9.46), and the modifier was acidic. It neutralized the OH^- ions in alkaline soil through exchanging ion, and adjusted the soil pH and created a micro environment suitable for the growth of oil sunflower. At the same time, free amino acids chelate cations such as Ca^{2+}, Mg^{2+} in the soil, reduced the hazard of Na^+ and promoted crop growth; The growth performance index of oil sunflower with "XIYOUFENG" soil amendment was the second, and the growth performance index of oil sunflower with desulfurized gypsum amendment was relatively poor. The modifier was applied to saline-sodic to optimize soil colloid composition, adjust soil pH, increase permeability between soil particles, regulate soil microenvironment, improve plant nutrient supply, and promote crop growth, and achieve the purpose of improving saline-sodic.

The yield and quality of oil sunflower were the direct embodiment of the improvement effect of saline-sodic, and directly affect the economic benefits of oil sunflower planting. The weight of 100 seeds was the key index to measure the yield and the basis for quality diagnosis. The larger the weight of 100 seeds, the higher the oil content. In addition, the nutritional characteristics and functional value of oil sunflower seed oil mainly depend on its fatty acid composition. The higher the content of unsaturated fatty acids, the more beneficial to health and the better the quality.

The effects of different modifiers on the yield and quality of oil sunflower are shown in Table 6. Soil amendment treatment was beneficial to crop nutrient absorption, significantly promoted crop growth and increased crop yield. The order of 100 seed weight, disc diameter and yield of oil sunflower in different treatments from large to small was MA > SA > FGD > CK, which increased respectively by 0.25~1.16 g, 2.63~6.67 cm, 282.07~1153.37 kg/hm^2 compared with CK. This was similar to the influence mechanism of different treatments on the growth performance of oil sunflower. The quality indexes of crude fat, crude protein, oleic acid, linoleic acid, linolenic acid and other quality indexes of oil sunflower in different treatments were in the order of MA > SA > FGD > CK, which were increased respectively by 0.30~0.66, 0.02~0.17, 0.05~0.15, 0.41~1.00, 0.32~1.31 g/100 g compared with CK. Different soil amendments can improve the alkalinity of soil and play a role in improving soil salinization, which was conducive to oil sunflower to absorb more nutrients and improve quality. On the other hand, sheep manure contains many organic acids and sugars. Under the action of organic acids and microorganisms, many "YUEYUYUAN" microbial agents were produced. Applying sheep manure to the soil was also conducive to improving the soil. Sheep manure contains many "nitrogen, phosphorus and potassium" elements, which were relatively mild in sheep manure. At the same time, it also contains more calcium, magnesium, sulfur, copper, zinc, iron, boron, molybdenum and other trace elements necessary for plants. These nitrogen, phosphorus, potassium and sugars in nutrients, after being absorbed by oil sunflower, improved the quality of oil sunflower, so that the quality of oil sunflower in CK was almost the same as that in other treatments.

Table 6. Effects of different treatments on Yield and quality of oil sunflower.

Units	hundred-grain weigh/g	Disc diameter cm	Yield kg/hm^2	Crude fat g/100g	Crude protein g/100g	Oleic acid g/100g	Linoleic acid g/100g	Malic acid g/100g
FGD	5.01 ± 0.02c	14.76 ± 0.06c	1878.56 ± 75.57c	17.38 ± 0.26ab	2.20 ± 0.03bc	2.82 ± 0.02ab	53.36 ± 0.23bc	35.96 ± 0.20bc
SA	5.21 ± 0.08b	16.67 ± 0.02b	2062.96 ± 50.38b	17.65 ± 0.15a	2.28 ± 0.03ab	2.88 ± 0.04a	53.68 ± 0.30ab	36.39 ± 0.23b
MA	5.92 ± 0.06a	18.89 ± 0.02a	2749.86 ± 50.381a	17.74 ± 0.05a	2.35 ± 0.02a	2.92 ± 0.05a	53.95 ± 0.17a	36.95 ± 0.11a
CK	4.76 ± 0.08d	12.13 ± 0.06d	1596.49 ± 75.57d	17.08 ± 0.21b	2.18 ± 0.04c	2.77 ± 0.05b	52.95 ± 0.17c	35.64 ± 0.14c

Different letters in the same row indicate significant differences ($p < 0.05\%$) among different treatments (Data processing system Origin 2021).

Saline-sodic management was a complex, long-term, and systematic project. The comprehensive utilization of saline-sodic has become a national strategic issue, and the saline-sodic management was in the stage of comprehensive regulation in China now. After years of exploration and practice, saline-sodic management has formed two paths of "Land adaptation for crops" and "Land adaptation for crops", and four measures of physical, chemical, biological, and comprehensive management to improve the quality of farmland land. This study was conducted in Wangtanzi Village, Dingbian County, Yulin City to investigate the effects of applying different soil amendments on oil sunflower yield and soil physico and chemical properties in severely saline-sodic treated with engineering measures (replacing drainage with storage and covering with sand). Studies have shown that switching to storage and sand covering projects reduces the average soil salinity by 55.5% (Han 2009), but corresponding measures were still needed to improve soil quality, because the three-phase structure and nutrient supply of soil were key factors for healthy crop growth and yield improvement. The soil pH, bulk density, and total salt content were reduced respectively by 5.87, 3.33, and 2.27% by planting oil sunflower. The results of this study were like those of previous studies. After planting oil sunflower, soil bulk density and salinity were reduced, soil structure was improved, and soil nutrient supply capacity was increased (Qu 2020, Wang 2016).

The soil pH of saline-sodic was significantly reduced by 2.24~10.15%, the soil bulk density was reduced by 2.67~8.00%, the soil clay was reduced by 0.06~0.20%, the soil sand was reduced by 0.20~1.02%, and the soil silt was increased by 0.26~1.22%, which increased the internal porosity of the soil, effectively improved the soil aeration, and enhanced the water retention capacity of the soil surface by adding desulfurized gypsum, “XIYOUFENG” soil modifier and "YUEYUYUAN" microbial agent. At the same time, the total salt content of the soil was reduced by 0.82~15.76%, which destroyed the conditions for salt rise and played the role of salt separation, soil organic matter and hydrolysis Nitrogen, available phosphorus and available potassium increased by 15.65~56.55, 2.32~39.57, 49.75~95.48 and 5.33%~32.96%, respectively, which provided a better environment for the growth of oil sunflower and promoted the growth of crops, making the plant height and stem diameter increased by 1.50~9.02 and 0.84%~4.20%, respectively, The difference was significant ($p < 0.05$). The yield of crops increased by 17.67~72.24%, and the quality contents of crude fat, crude protein, oleic acid, linoleic acid, and linolenic acid increased by 1.76~3.86, 0.92~7.80, 1.81~5.42, 0.77~1.89 and 0.90%~3.68%, respectively. There were like the previous research results (Wang *et al.* 2020, Wu *et al.* 2021, Pang *et al.* 2023, Yang *et al.* 2025).

This study comprehensively applied chemical and biological improvement measures, and comparatively analyzed the effects of different soil improvement measures on soil pH, bulk density, soil structure, nutrient content, growth, yield and quality of oil sunflower on the basis of physical measures to control saline-sodic, Our findings provide a suitable amendments for saline-sodic and suggest that amendments is a promising method for salt-controlling and yield-increasing.

The addition of different modifiers can significantly reduce the soil pH and soil bulk density, optimize the composition of soil clay, sand and silt, increase the internal porosity of the soil, effectively improve the soil structure and aeration, enhance the water retention capacity of the soil surface, destroy the conditions for the rise of soil salinity, play the role of salt separation, effectively improve the soil environment, and create a good development space for crop growth in the saline-sodic.

The results showed that the addition of different modifiers could significantly improve the plant height and stem diameter of oil sunflower, increase the yield of Oil Sunflower by increasing the 100 seed weight and disc diameter of oil sunflower, and at the same time, the crude fat, crude protein, oleic acid, linoleic acid, linolenic acid and other quality indicators in sunflower seed oil were significantly improved in the saline-sodic.

Planting salt tolerant crops can improve the soil environment and reduce the total salt content of the soil. In addition, salt tolerant crops have the best soil physical and chemical properties, nutrient supply, crop quality and yield under the action of "YUEYUYUAN" microbial inoculant soil conditioner. Priority was given to planting salt tolerant crops in Northern Shaanxi, and applying "YUEYUYUAN" microbial inoculant soil conditioner for saline soil improvement can effectively improve the soil environment, promote crop growth, and increase crop economic benefits.

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