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Retraction

Retracted: Effects of Different Soil Modifiers on Salt Improvement and Distribution, Crop Growth of the Gully Land Consolidation on Loess Plateau

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] Y. Yang, B. Zhou, and L. Feng, "Effects of Different Soil Modifiers on Salt Improvement and Distribution, Crop Growth of the Gully Land Consolidation on Loess Plateau," *Journal of Sensors*, vol. 2022, Article ID 5282344, 17 pages, 2022.

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Research Article

Effects of Different Soil Modifiers on Salt Improvement and Distribution, Crop Growth of the Gully Land Consolidation on Loess Plateau

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Due to the strong evaporation and leakage loss, secondary saline-alkali was the main problem in the watershed of gully land consolidation on Loess Plateau. Through field farming experiments, five modifiers (maize stalk (MS), humus acid (HA), Yan Ke (YK), He Kang (HK), and nanobiochar (NB)) were studied to investigate the effects of these soil modifiers on soil water and salt distribution, leaf photosynthetic characteristics, and maize growth and yields, as well as economic benefits in secondary saline-alkali soils of gully land consolidation watershed on Loess Plateau in 2019 and 2020. The results showed that soil modifiers could increase the water-holding capacity of the soil, reduce the salt content of the soil profiles, and decompose the accumulation of salt. The maximum desalination rate obtained in 2019 and 2020 increased, respectively, by 71.57% and 46.02%, compared to that in the control treatment. Soil modifiers could increase the net photosynthetic rate (*Pn*), transpiration rate (*Tr*), stomatal conductance (*Gs*), and decreased the intercellular CO_2 concentration (*Ci*). The output increased by 13.63%-31.84%, and revenue increased by 6.48%-38.01%. According to analyzing the production of soil modifier application, we found that the highest net profit was achieved when HK application rate was 52.4 kg/ha. Therefore, this study suggested that 52.4 kg/ha might be recommended as an appropriate soil modifier application strategy to deal with crop growth and improve economic benefit in secondary saline-alkali soils of Northwest China.

1. Introduction

Land degradation caused by irrational human activities has seriously threatened the sustainability development of world agriculture [1–3]. According to statistics, 65% of the world's land has been degraded, and secondary saline-alkali is a major manifestation of soil degradation [4]. In the early 20th century, due to the large-scale returning farmland to forest, the area of cultivated land decreased in some areas of the Loess Plateau [5, 6]. In order to control the decrease of cultivated land area, gully land consolidation area construction was conducted in the Loess Plateau basin [7]. Though such construction measurement effectively increased local cultivated land area, some problems such as secondary saline-alkali occurred with strong evaporation, leakage loss, and high salt contents in underground water with low groundwater level [8]. Secondary saline-alkali has become one of the serious obstacle to crop growth and yield in this area.

Hydraulic engineering was adopted initially by many researchers, but the construction cost was high. During the construction period, crop farming will be affected as well [9–11]. Biological improvement methods are beneficial for crops that are resistant to disease, salt, insect pests, and drought but improper use may bring about harm to biodiversity. Thus, there is still a long way to before we safely used those biological methods [12–14]. Physical improvement methods mainly include isolation layer salt control, straw covering, irrigation leaching, drainage leaching, irrigation, and drainage combined leaching [15, 16]. The isolation layer and straw mulch are mainly used to reduce surface temperature and cut off the contact surface between the soil surface

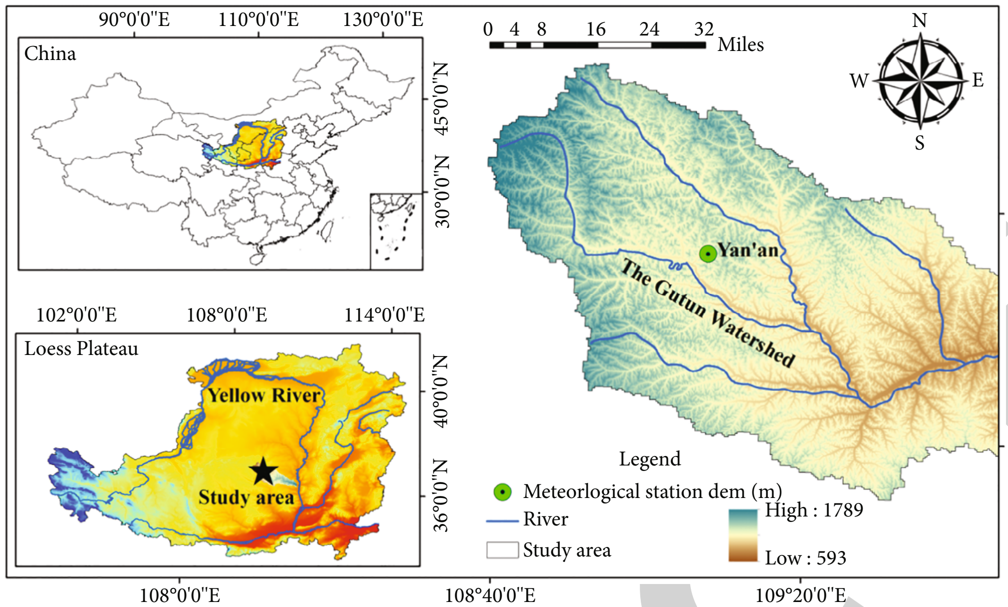


Figure 1: Location of research site.

and air, thus slowing down phreatic water evaporation, reducing the upward accumulation of salt, and inhibiting the accumulation of salt surface [17, 18].

Chemical improvement method is also an effective way in improving soil structure, promoting salt leaching, and adjusting soil pH. Nanocarbon has a good effect on improving saline-alkali soil and promoting crop growth and development [19, 20]. Humus acid (HA) can regulate soil, effectively improve soil structure, increase soil organic matter, reduce soil salinity, promote crop growth, and increase crop yield [21–23]. Yan Ke (YK) has the ability of ion exchange property, which can effectively reduce the concentration of exchangeable sodium and other salt ions in the soil, improve the physical and chemical properties of the soil, improve the nutrient absorption environment of crops, and regulate the soil pH. HK can reduce the toxicity and osmotic pressure caused by salt molecules by combining organic macromolecules with salt ions in the soil, improve the physical and chemical properties of the soil, increase water and nutrients, and improve the drought-resistant ability of crops [24–26]. These methods can improve saline-alkali soil conditions and are more effective than traditional ones. Some things to note are that the test results of these studies are only obtained through laboratory experiments and soil column simulated experiments. However, the research of soil modifiers under field conditions is still not system experiments. In consequence, we assume that adding soil modifiers into the secondary saline-alkali soils can improve the formation of soil water and salt distribution, stimulate crop growth and crop yields, and enhance economic benefit under field conditions. Therefore, in the past two years from 2019 to 2020, we conducted a consecutive field experiment in the Loess Plateau region.

This article carries out systematic research on the effectiveness of 5 currently rapidly developed soil modifiers (MS, HA, YK, HK, and NB) in improving the fertility of secondary saline-alkali soil and promoting the growth of typical crops and thus expects to provide implications to the improvement of secondary saline-alkali soil and of the growth of crops.

2. Materials and Methods

2.1. Introduction to Research Site. Field experiments were conducted during the maize (Xianyu 1483) growing seasons in May to October in 2019 and 2020. The station (latitude 36°45′16″–36°50′24″N, longitude 109°46′18″–109°51′05″E) is located in Ganguyi Town, Yan'an City, Shaanxi Province, China. The basin is located in the middle temperate semiarid region with a total length of 12.5 km and an area of about 2435 km^2 (see Figure 1). The annual average temperature was 10.3°C. The maximum and minimum temperature are -17.4°C and 30.3°C. The annual mean precipitation is 4947 mm [8]. The rainfall in 2019 and 2020 is concentrated from June to October (Figure 2), and the rainfall in 2019 and 2020 growing seasons is 4060 mm and 5146 mm, respectively. The average daily temperature in the growing season (May-October) in 2019 and 2020 was 25.2°C and 24.1°C, respectively (Figure 2). The soil types in the basin include black loess, red soil, and loessal. The soil in the experiment fields belonged to sandy soil. The basic physical and chemical properties in the initial soil profile are shown in Table 1.

2.2. Experimental Materials. The tested maize variety was Xianyu 1483 and can be cropped on sandy soil and suitable local cultivation. The tested He Kang soil modifier (HK) was a crop nutrition type (formulation-type medium) with a density of 1.1 g/cm^3-1.2 g/cm^3 and a pH of 2.0-3.0. The tested maize stalk (MS) was local straw, which was dried

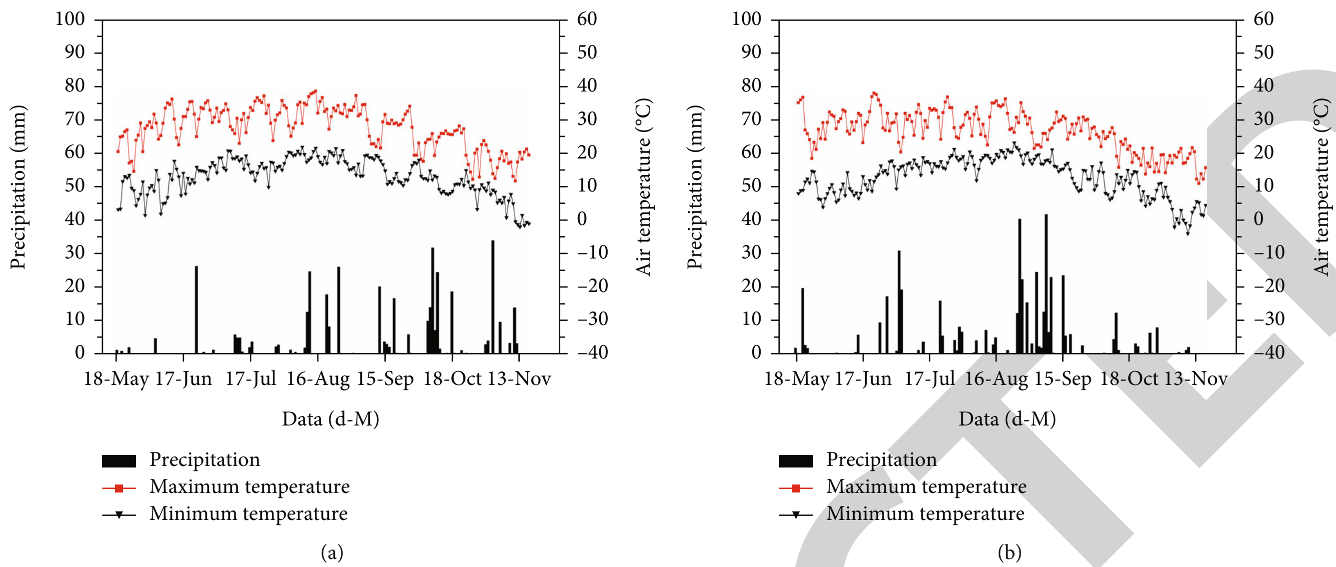


FIGURE 2: Distribution of precipitation and mean air temperature at the studied area during the maize growing seasons of (a) 2019 and (b) 2020.

and broken into pieces of about 2 mm. The humus acid (HA) soil modifier was from Shaanxi Meike Biotechnology Co., Ltd., $K_2O \geq 8.0$, humus acid $\geq 55\%$, and fulvic acid ≥ 37 %. Yan Ke (YK) soil modifier is from Shaanxi Meike Biotechnology Co., Ltd., and soluble organic carbon $\geq 45\%$, $(N + P_2O_5 + K_2O) \geq 40\%$. Nanobiochar (NB) is a black powder. The prepared nanobiochar has a pH of 9.6, a volume density of 0.38 g/cm^3, and a diameter of 40 nm. The tested compound fertilizer was "Meffro," with the total nutrient $(N + P_2O_5 + K_2O) \geq 40\%$.

2.3. Experiment Treatment. The experimental plot was the local agricultural land. The maize was sown between May 4 and 6 and then harvested on October 9 and 1, in 2019 and 2020, respectively. Maize seed density was 56700 crops/ha^{-1}, with a row spacing of 50 cm and between the crop pacing of 25 cm. In the experimental design, five different soil modifier contents (52.4 kg/ha (HK), 48.4 kg/ha (MS), 11.3 kg/ha (HA), 86.1 kg/ha (NB), and 45.0 kg/ha (YK)) were mixed well with 0-20 cm surface soil and then applied into the soil layer.

Plots without soil modifier adding were used as controls (CK). Each plot had 3 replicates and 18 experimental plots. Before sowing, 0.864 kg phosphate fertilizer (P_2O_5), 1.558 kg nitrogen fertilizer (N), and 0.854 kg potassium fertilizer (K_2O) were evenly applied in experimental plots. Irrigate the plots before maize sown.

2.4. Experimental Project and Methods

2.4.1. Determination Method of Soil Water Content, Salt Content, Available Nutrients, and Leaf Photosynthetic Characteristics. Five points of each plot in different growth stages (seedling stage, shooting stage, tasselling stage, filling stage, and maturation stage) of maize were sampled in a "*S*" sampling method, and soil samples of 0-2, 2-4, 4-6, 6-8, 8-10, 10-15, 15-20, 20-25, 25-30, 30-35, and 35-40 cm soil layers were collected by soil drill in layers and placed in sampling bags in layers for testing. Soil particle composition was measured by mastersizer-2000 laser particle size analyzer. Soil water content in different soil layers at different growth stages was randomly measured by Watchdog moisture sensor. The leaves, stems, and roots from maize were also randomly measured at the same growth stages (seedling stage, shooting stage, tasselling stage, filling stage, and maturation stage). At the different farmland soil profile depths, the soil moisture content was determined by the Trime-pico32 TDR soil moisture sensor. The salt content of the different farmland soil profiles was measured by DDSJ-308 conductivity instrument. At filling stage, maize plant of three in each plot was chosen and the maize leaf photosynthetic characteristics were measured on sunshine day at 10 AM. The net photosynthetic rate (*Pn*), transpiration rate (*Tr*), stomatal conductance (*Gs*), and intercellular CO_2 concentration (*Ci*) were determined by the CIRAS-3 portable photosynthetic measurement system.

2.4.2. Crop Height, Stem Diameter, Leaf Area, and Yield. At different maize growth stages (seedling stage, shooting stage, tasselling stage, filling stage, and maturation stage), three representative maize crops were randomly selected from each plot in 2019 and 2020. The crop height and stem diameter of the maize were measured by ruler and caliper, and the yield was weighed by scale with the precision of 0.01 g.

2.5. Data Processing and Analysis

2.5.1. Soil Salt Content Analysis. Given a stable salt composition, the level of soil salt content (SSC) can be reflected by soil electrical conductivity (SEC), with a linear relationship between them [27]. Based on the analysis of the soil samples, we had the calibration curve of soil salt content and electrical

Table 1: The physical and chemical properties of the soil of experimental plot.

Soil	Depth (cm)	Soil bulk density ($g\cdot cm^{-3}$)	Particle content (%) Clay <0.002 mm	Particle content (%) Silt 0.002-0.02 mm	Particle content (%) Sand 0.02-2 mm	pH	Total salt ($g\cdot kg^{-1}$)	Organic matter ($g\cdot kg^{-1}$)	Total nitrogen ($g\cdot kg^{-1}$)	Available phosphorus ($g\cdot kg^{-1}$)	Available potassium ($g\cdot kg^{-1}$)
Sandy soil	0-20	1.58	5.88	34.17	59.95	8.41	2.84	6.14	0.39	13.61	130.67

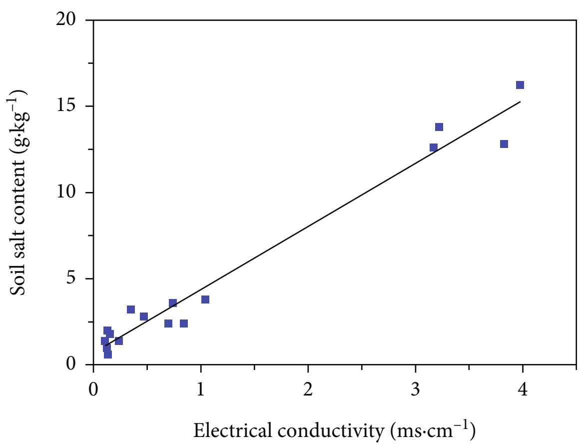


Figure 3: Relationship between soil salt content (SSC) and electrical conductivity (SEC) of soil extract.

conductivity of soil leaching solution (see Figure 3). The fitted relationship between SSC and SEC of soil leaching solution was illustrated as follows:

$$EC = 3.6485S + 0.7319, \quad R^2 = 0.9703, \tag{1}$$

where S is the soil electrical conductivity (SEC) value and EC is soil salt content (SSC) of the soil extract.

2.5.2. Cost–Benefit Analysis. In this study, net income per unit area is taken as the economic benefit evaluation index. The input of maize production mainly includes the cost of seeds, fertilizers, pesticides, and other agricultural means of production, as well as the cost of renting land, agrolabor management, and the cost of maize harvesting. Maize production income mainly comes from maize kernel sales. The difference between maize kernel sales revenue per unit area and production input is the net income per unit area, which is calculated according to the following formula (the results are shown in Table 2).

$$F = Y \times P_1 - (Y \times P_2 + L \times P_3 + S \times P_5 + Z + N + H + J), \tag{2}$$

where F is net income per hectare, ¥·ha^{-1}, Y is yield, kg·ha^{-1}, P_1 is the purchase price of maize rains, ¥·ha^{-1}, P_2 is the unit price of maize harvesting, ¥·ha^{-1}, L is the unit price of the modifier, ¥·ha^{-1}, P_3 is the amount of improver per unit area, ¥·ha^{-1}, S is the sowing amount per unit area, ¥·ha^{-1}, P_5 is the unit price of maize seed, ¥·ha^{-1}, Z is the rental fee per unit area, ¥·ha^{-1}, N is the farmland management fee per unit area, ¥·ha^{-1}, H is the cost of chemical fertilizers and pesticides per, ¥·ha^{-1}, and J is cropping cost, ¥·ha^{-1}.

2.5.3. Statistical Analysis. The data were the mean value of three replicates. Microsoft Excel 2010 and SPSS Statistics 17.0 software were used for statistical analysis (ANOVA) and charting of relevant parameters. The least significant difference (LSD) tests at $P < 0.05$ level were used to determine significant differences between the treatments. Origin Function software, Arcgis 10.2, and Microsoft Visio 2003 were used to draw figures.

3. Results

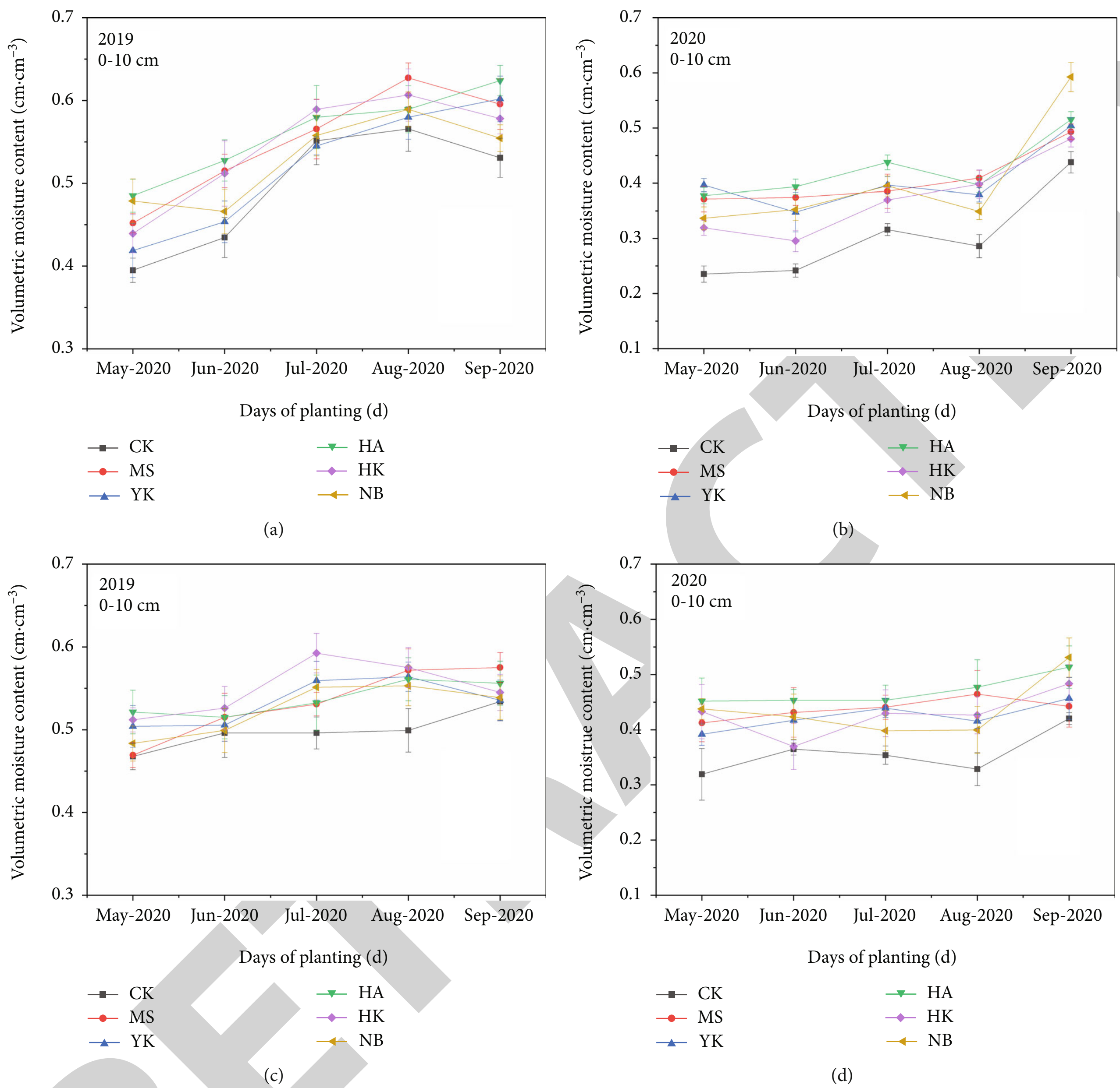
3.1. Effects of Different Soil Modifier Contents on the Distribution of Water and Salt in Soil Profile

3.1.1. Effects of Different Soil Modifier Contents on Moisture Content of Soil Profile. Because of the high precipitation in the experimental area during the maize growth period, the farmland was not irrigated [8]. Figure 4 describes the effects of different soil modifiers on the soil profile water content in the field of the test plot in each growth stage of maize. It can be seen that in the whole maize growth period 0-40 cm soil profile, because of the plot in maize, temperatures, and sunshine time extension, and farmland is not in the water supply moisture to the soil, the test of soil evaporation is higher, and the surface soil moisture content is low. With the increase of soil depth, the influence of evapotranspiration on the deep soil layer gradually decreases, and the soil water content gradually increases. Compared with CK, the soil moisture content of 0-10 cm surface soil under different soil modifier treatments was all higher than that of CK. The variation of soil water content was the most obvious after adding HA and showed the same trend in 2019 and 2020. The 10-20 cm soil moisture content curve also showed a trend of fluctuation due to the addition of soil modifier, but the fluctuation of the curve was smaller than that of the surface soil in general. On the whole, the soil moisture content of 20-40 cm fluctuated steadily with the growth stage. Soil water contents in HA plots were the largest in tasseling stage and filling stage, while the water content of HK treatment decreased the least from filling to maturity stage. Thus, the addition of soil modifiers can increase the water holding capacity of the soil.

3.1.2. Effects of Different Soil Modifier on the Soil Salt Content of Farmland in Different Growth Periods of Maize. The measured conductivity value was put into Equation (1) to calculate the soil profile salt content of each treatment, and it follows the relation diagram of the change of soil profile salt content in the whole growth period in the field of the test plot with different soil modifiers shown in Figure 5. It can be seen that the changing trend in 2019 and 2020 is the same, that is, during the entire growth period, the overall trend of the 0-40 cm soil profile turns out to have higher salt content in the surface layer. As the depth of the soil profile increases, the salt content of the soil gradually decreases. Compared with the impact on the salt content of maize with CK, the addition of soil modifiers has a more significant impact on the salt content of the soil profile. After the addition of soil modifiers, the salt content of the soil profile is significantly less than that of CK. Based on further analysis of Figure 5, it can be seen that in 2019 and 2020, the salt content of the soil profile at 0-20 cm changes most obviously, and the group with CK is significantly higher than the test group with the soil modifiers. In addition,

Table 2: Maize planting, harvesting, and selling prices.

Category	Selling price (¥·kg^{-1})	Farm machinery (¥·ha^{-1})	Maize seeds (¥·ha^{-1})	MS price (¥·kg^{-1})	YK price (¥·ha^{-1})	HA price (¥·ha^{-1})	HK price (¥·kg^{-1})	NB price (¥·ha^{-1})	Land rentals (¥·ha^{-1})	Farmland management fee (¥·ha^{-1})	Chemical fertilizers (¥·ha^{-1})
Price	3	750	300	242	900	169	1048	1322	1500	1000	750



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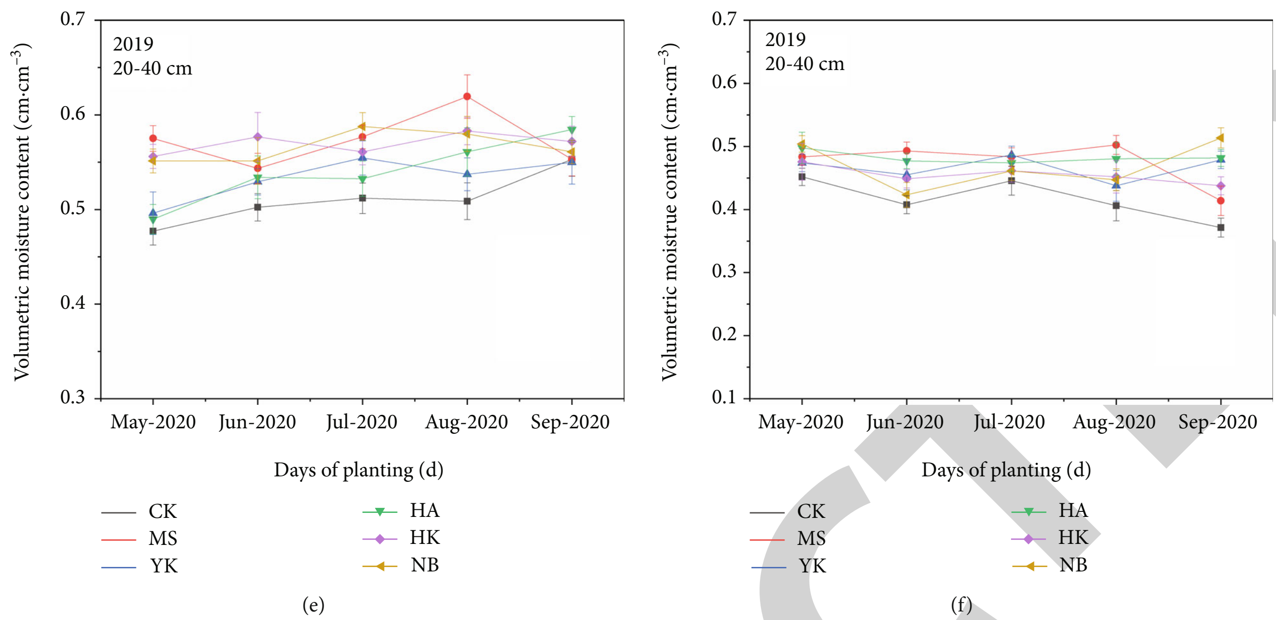

Figure 4: Distribution of the effect of different soil modifier contents on soil profile moisture content of (a) 0-10 cm, 2019, (b) 0-10 cm, 2020, (c) 10-20 cm, 2019, (d) 10-20 cm, 2020, (e) 20-40 cm, 2019, and (f) 20-40 cm, 2020, respectively.

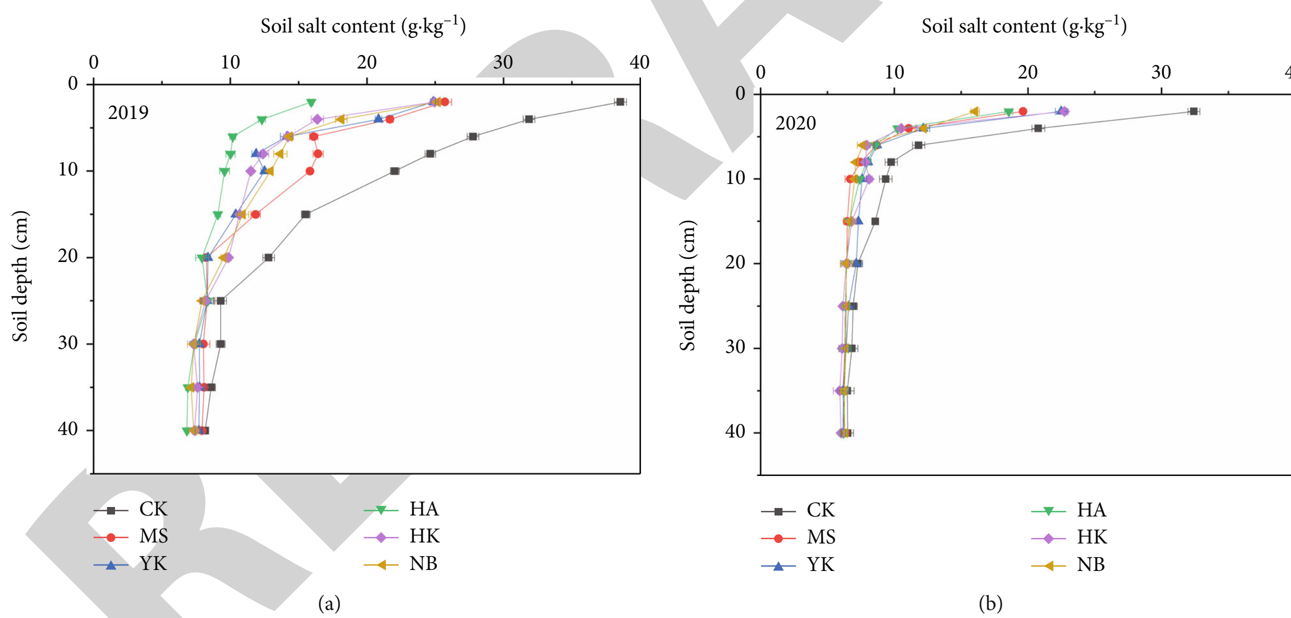

Figure 5: Distribution of the effects of different soil modifier on soil profile salt content during the whole growth period of (a) 2019 and (b) 2020.

the effect of soil modifiers on salt distribution in 2019 is more obvious. Such trend attributes to the temperature in 2019 are high, and the amount of precipitation is less than in 2020, so the improvement effect in 2019 is more obvious.

3.1.3. Effects of Different Soil Modifiers on the Salt Distribution of Farmland in Different Growth Periods of Maize. According to the measured data, Figure 6 illustrates the changes of different soil modifiers on farmland salt distribution in 0-10 cm (a), 10-20 cm (b), and 20-40 cm (c) in each maize growth period in 2019 and 2020. It can be seen 0-40 cm soil layer has higher salt content compared to that in 0-10 cm and 10-20 cm soil layer. With the increase of soil profile depth, the salt content of the 20-40 cm soil layer gradually decreases. The effect of soil modifiers on the soil salt content is more significant, which is shown as the salt content of the test plots with soil modifiers less than that of CK. With the growth of maize, the overall soil salt content

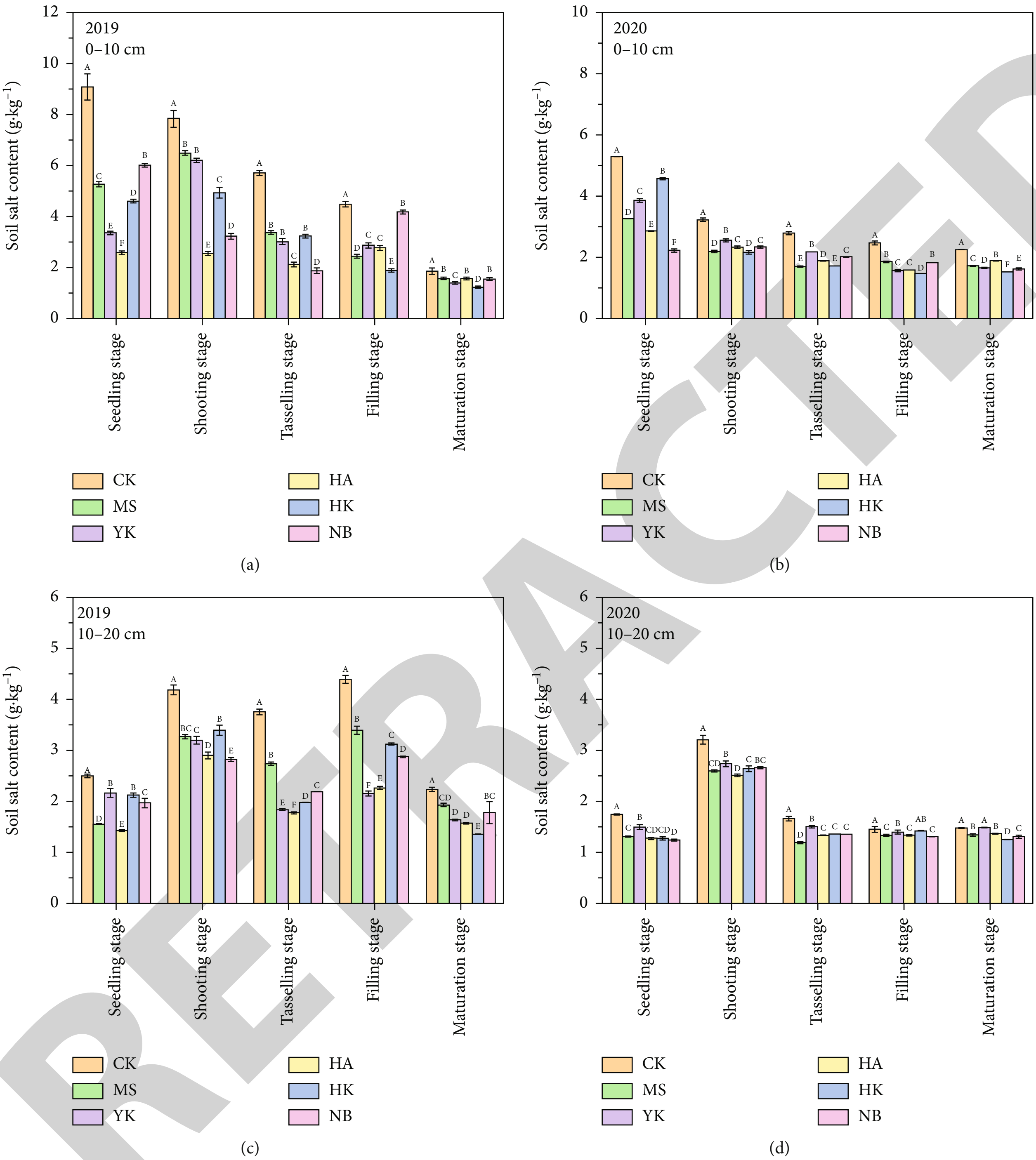

Figure 6: Continued.

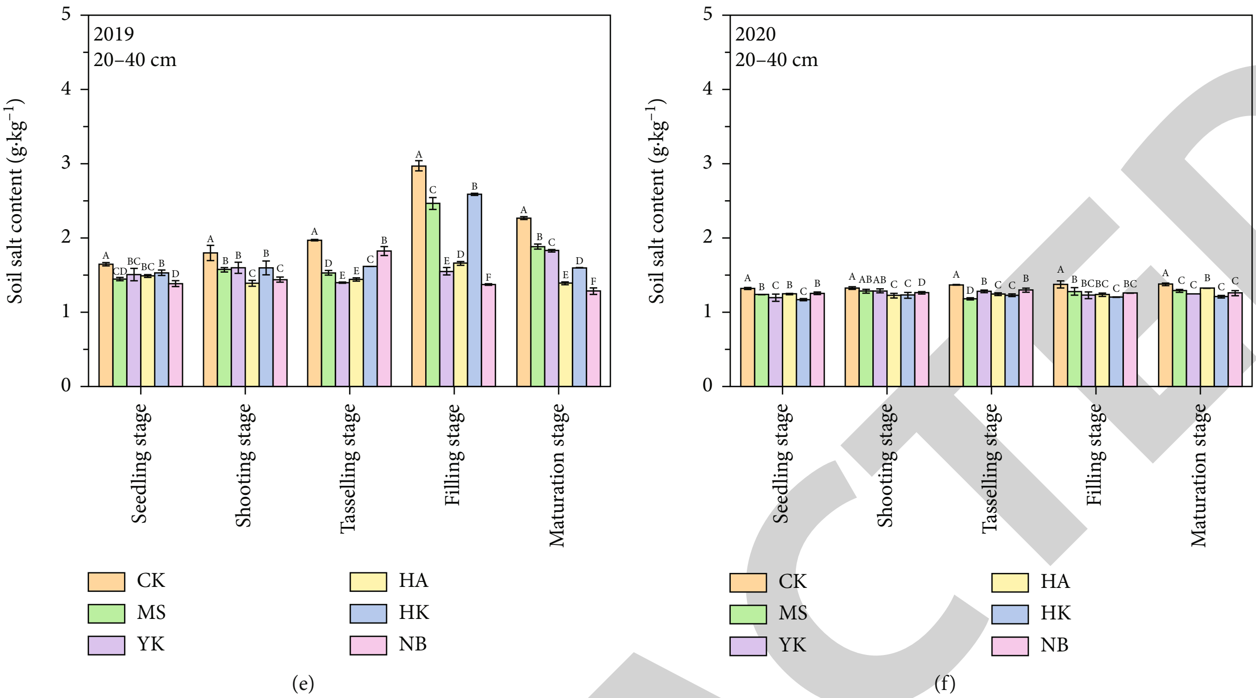

Figure 6: Distribution of the effects of different soil modifiers on the dynamic changes of soil salinity in the growing period of (a) 0-10 cm, 2019, (b) 0-10 cm, 2020, (c) 10-20 cm, 2019, (d) 10-20 cm, 2020, (e) 20-40 cm, 2019, and (f) 20-40 cm, 2020, respectively.

increased first and then decreased. It is also shown in Figure 6 that compared to CK, soil modifiers have more obvious effects on the salt distribution in the shooting stage, tasseling stage, and the filling stage. Such results mainly attributed to the high temperature, the high evaporation strength, and low rainfall. Therefore, it can be seen that applying soil modifiers can reduce evaporation while reducing the accumulation of salt.

By subtracting the salt content of different soil modifiers in each soil layer from the salt content of CK and dividing by CK, it follows the results of the influence of different soil modifiers on the desalination rate of soil layer in 2019 and 2020 (see Table 3). It can be seen from Table 3 that the desalination effect of each test plot varies greatly with the soil depth during the whole growth period of maize. In each growth period, the desalination rate of soil profile increased with different soil modifiers agents. In the 0-40 cm section, the desalination effect at seedling, shooting, and tasseling stages was better than that at filling stages and maturation stages. At the seedling stage of 0-10 cm, the trend of 2019 and 2020 was consistent, that is, the test plots with HA added had the best desalination, which was 71.57% and 46.02%, respectively. In the 10-20 cm section, the desalination rate of the HA test plot was the highest at the tasseling stage, 51.92%. In the 20-40 cm section, the desalination rate of the YK test plot at the filling stage is the highest of 47.8%.

3.2. Effects of Different Soil Modifiers on the Growth, Yield, and Economic Benefit of Maize

3.2.1. Effects of Different Soil Modifiers on Maize Growth. The seedling growth of maize was slow, and there was no significant difference in crop height, leaf area, and stem diameter between different soil modifiers treatments. After entering the shooting stage (60 days), a significant difference in different soil modifiers could be found in the crop height, leaf area, and stem diameter. After the tasseling stage (90 days), the growth rate of maize crop height decreased and then was stabilized, and the leaf area and stem diameter decreased gradually after reaching the maximum (Figure 7).

3.2.2. Effects of Different Soil Modifiers on Leaf Photosynthetic Characteristics of Maize. The effect of the five soil modifiers on leaf photosynthetic characteristics of maize at the filling stage are shown in Table 4. Table 4 shows that compared with the CK, soil modifier can significantly influence the leaf photosynthetic characteristics of maize. The influence of leaf photosynthetic characteristics varies from different modifiers. In order to clarify the influence of the soil modifiers on the experimental results, one-way ANOVA was conducted on the net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs), and intercellular CO_2 concentration (Ci) ($P < 0.05$), and the results are listed in Table 4. It can be seen that the application of soil modifier has a very significant correlation with the net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs), and intercellular CO_2 concentration (Ci), and the P value is far less than 0.01, so the application of soil modifier has a very significant effect ($\alpha = 0.05$). It can be seen that the application of soil modifiers can increase the net photosynthetic rate (Pn), transpiration rate (Tr), and stomatal conductance (Gs) and decrease the intercellular CO_2 concentration (Ci).

Table 3: Effects of soil modifier contents on desalinization rates in different growth stages.

Soil modifier/(g·m^{-2})	Growth stages	Soil depth/(cm) 2019			2020		
		0-10	10-20	20-40	0-10	10-20	20-40
MS	Seedling stage	41.98%	37.96%	1.85%	38.34%	25.01%	6.13%
	Shooting stage	14.74%	21.97%	1.56%	32.06%	19.16%	3.33%
	Tasselling stage	25.69%	27.06%	16.07%	39.32%	28.48%	7.92%
	Filling stage	22.54%	22.75%	16.97%	25.06%	8.02%	6.98%
	Maturation stage	3.19%	-15.92%	16.80%	23.67%	9.25%	6.63%
YK	Seedling stage	63.03%	13.42%	4.30%	27.11%	14.22%	9.23%
	Shooting stage	17.91%	23.62%	11.08%	20.90%	14.79%	2.89%
	Tasselling stage	29.61%	51.04%	23.31%	22.23%	9.52%	-6.35%
	Filling stage	17.81%	50.96%	47.80%	36.75%	4.02%	10.54%
	Maturation stage	5.10%	15.30%	19.34%	26.35%	-0.49%	9.50%
HA	Seedling stage	71.57%	42.93%	2.87%	46.02%	26.82%	5.37%
	Shooting stage	58.08%	30.72%	13.07%	27.75%	21.80%	7.66%
	Tasselling stage	39.46%	51.92%	20.91%	32.64%	20.05%	3.18%
	Filling stage	18.92%	48.47%	44.19%	35.72%	8.32%	9.88%
	Maturation stage	3.17%	18.52%	38.64%	16.03%	7.62%	3.88%
HK	Seedling stage	49.26%	15.10%	5.94%	13.65%	27.03%	11.21%
	Shooting stage	31.86%	18.92%	-12.60%	33.00%	17.90%	7.26%
	Tasselling stage	27.26%	47.32%	11.29%	38.54%	18.25%	4.17%
	Filling stage	28.64%	28.90%	12.85%	40.84%	2.13%	12.34%
	Maturation stage	6.98%	29.85%	29.55%	32.35%	15.26%	12.25%
NB	Seedling stage	33.79%	21.34%	4.28%	38.01%	28.84%	4.71%
	Shooting stage	50.69%	32.64%	10.02%	27.69%	17.12%	4.89%
	Tasselling stage	42.23%	41.66%	18.02%	28.05%	18.53%	-1.20%
	Filling stage	3.36%	34.55%	53.86%	26.07%	9.82%	8.28%
	Maturation stage	3.44%	7.73%	43.36%	27.97%	11.59%	8.63%

3.2.3. Effects of Different Soil Modifiers on Maize Yield. Table 5 shows that compared with the CK, soil modifier can significantly increase the thousand kernel weight and yield of maize. The increase of maize yield varies from different modifiers. The average yield of maize with MS, YK, HA, HK, and NB applied in 2019 was 13.63%, 13.76%, 15.09%, 21.12%, and 23.84% higher than maize with CK, respectively, and in 2020 18.42%, 16.65%, 23.31%, 29.68%, and 31.84%, respectively. The yield increase rate of maize that applied all the five soil modifiers showed an increase in 2019 and 2020 (NB>HK>HA>YK>MS). In order to clarify the influence of the soil modifiers on the experimental results, one-way ANOVA was conducted on the 1000-grain weight and yield ($P < 0.05$), and the results are listed in Table 5. It can be seen that the application of soil modifier has a very significant correlation with the 1000-grain weight and yield, and the P value is far less than 0.01, so the application of soil modifier has a very significant effect on the yield ($\alpha = 0.05$). It can be seen that the application of soil modifiers has an important effect on maize yield.

3.2.4. Effects of Different Soil Modifiers on Economic Benefits of Maize. The economic benefit is another important indicator to estimating cropping patterns. When calculating the income per hectare, this study conducted an investigation on the agricultural materials market of Yan'an city in 2018 and 2019 and obtained the relevant parameters in Equation (2) (Table 2). Through calculation and investigation statistics, the expenditure and gross income of each unit area under the application of different modifiers are obtained, as shown in Table 6. It follows that the rank of upfront expenses of maize with the five soil modifiers is NB>HK>YK>HA>MS>CK. The expenditure in the later stage is the same because of the same harvesting mode. By comparing the net income in 2019 and 2020, it can be seen that, compared with CK, the net income after applying soil modifier is higher than that of CK, and the net income of the experimental plots in HK is the highest, increasing by ¥ 3257.74 and ¥ 2168.23, respectively. The overall net income is HK>HA>YK>MS>NB>CK.

4. Discussion

4.1. Influence of Different Soil Modifiers on Water Content in Maize Field. In agriculture production, soil modifiers had great potential for water-saving [16, 20, 26, 28]. And it could

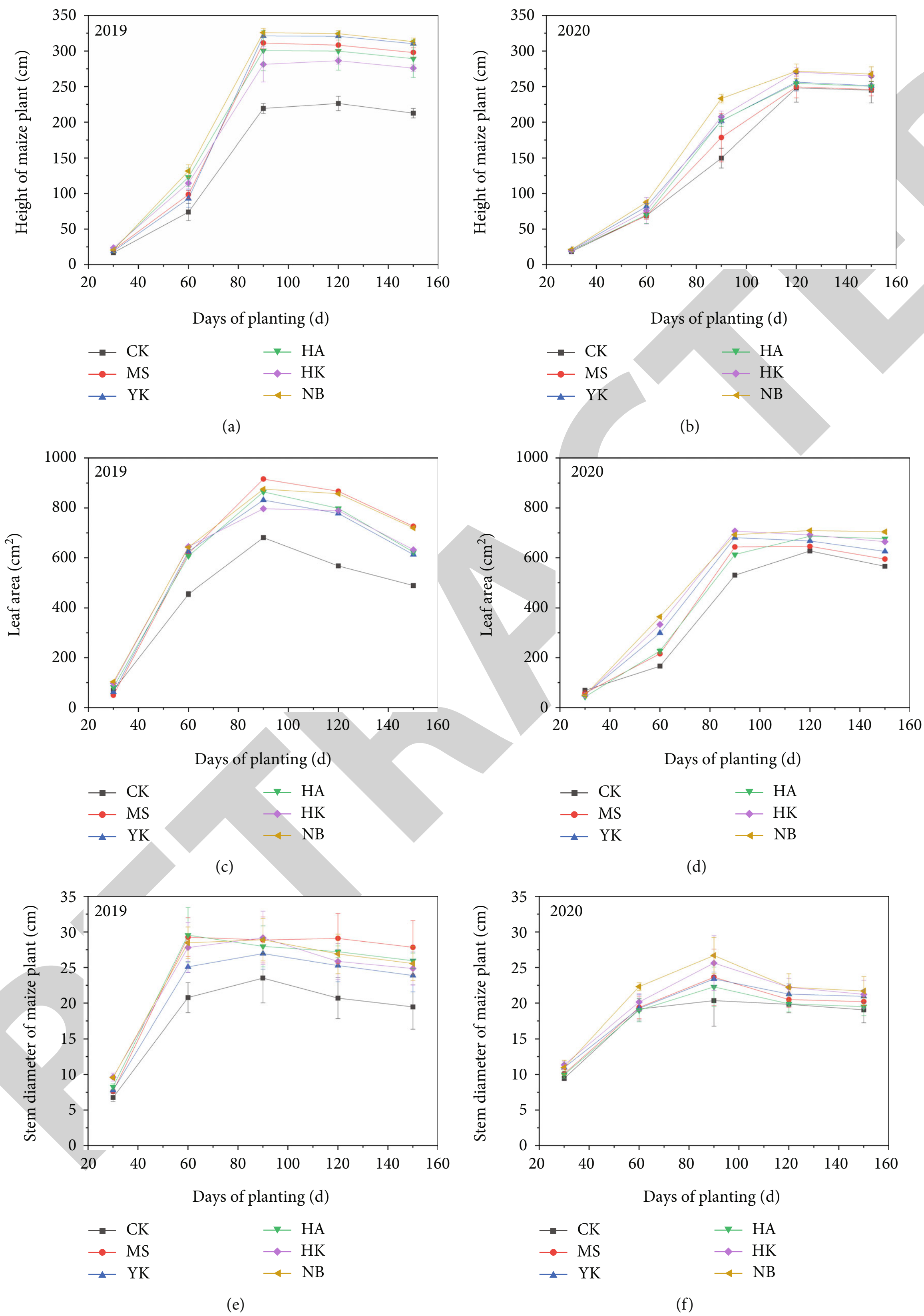

Figure 7: Distribution of the effects of different soil modifiers on maize growth of (a) height of maize plant, 2019, (b) height of maize plant, 2020, (c) leaf area, 2019, (d) leaf area, 2020, (e) stem diameter of maize plant, 2019, and (f) stem diameter of maize plant, 2020, respectively.

Table 4: The effects of different soil modifiers on leaf photosynthetic characteristics.

Year	2019				2020			
Plot	Pn/(μmol CO_2/(m^2·s))	Gs/(μmol/(m^2·s))	Ci/(μL/L)	Tr/(mmol H_2O/(m^2·s))	Pn/(μmol CO_2/(m^2·s))	Gs/(μmol/(m^2·s))	Ci/(μL/L)	Tr/(mmol H_2O/(m^2·s))
CK	23.21 ± 2.23^e	0.1 ± 0.03^c	331.69 ± 44.00^a	3.21 ± 0.70^d	20.12 ± 1.93^e	0.09 ± 0.03^c	287.57 ± 38.15^a	2.79 ± 0.60^d
MS	26.27 ± 0.76^d	0.25 ± 0.08^b	316.41 ± 60.20^a	3.99 ± 0.53^c	24.12 ± 0.70^d	0.23 ± 0.07^b	290.46 ± 55.26^a	3.66 ± 0.49^c
YK	27.2 ± 2.27^d	0.21 ± 0.04^b	288.39 ± 21.73^b	4.24 ± 0.42^b	25.39 ± 1.72^d	0.19 ± 0.03^b	258.68 ± 19.49^b	3.81 ± 0.38^c
HA	31.25 ± 2.44^c	0.23 ± 0.04^b	275.69 ± 30.14^b	4.26 ± 0.20^b	30.03 ± 2.35^c	0.22 ± 0.04^b	264.94 ± 28.97^b	4.09 ± 0.19^b
HK	33.12 ± 2.45^b	0.31 ± 0.08^a	248.48 ± 19.11^c	5.67 ± 0.87^a	34.2 ± 2.80^b	0.3 ± 0.08^a	212.84 ± 33.97^c	5.28 ± 0.85^a
NB	36.44 ± 1.04^a	0.34 ± 0.03^a	208.14 ± 34.55^d	5.21 ± 0.35^a	35.27 ± 1.00^b	0.33 ± 0.03^a	201.48 ± 33.44^d	5.05 ± 0.34^a
P	1.75×10^{-7} **	1.43×10^{-2} **	3.68×10^{-8} **	4.53×10^{-2} **	1.54×10^{-6} **	1.40×10^{-2} **	$1.56 \times 10^{-8*}$ *	$8.76 \times 10^{-2*}$ *

Note: Data in the table are mean ± standard deviation. Different letters in the same column represent significant differences between different treatments at the 0.05 level (Duncan's method). ** indicates that there is a very significant correlation between experimental factors and results ($P < 0.01$).

Table 5: The effects of different soil modifiers on maize grain yield.

Year	2019			2020		
Plot	1000-grain weigh/(g)	Yield/(kg·ha^{-1})	Increase over control/(%)	1000-grain weigh/(g)	Yield/(kg·ha^{-1})	Increase over control/(%)
CK	290.05 ± 1.04^{d}	3695.22 ± 78.11^{c}	-	274.54 ± 2.46^{e}	3204.58 ± 38.57^{d}	-
MS	415.07 ± 0.87^{b}	4278.43 ± 90.51^{b}	13.63	323.88 ± 4.84^{d}	3928.34 ± 186.49^{c}	18.42
YK	378.64 ± 3.77^{c}	4285.07 ± 244.46^{b}	13.76	396.67 ± 7.44^{b}	3844.96 ± 20.32^{c}	16.65
HA	368.95 ± 0.95^{c}	4347.55 ± 233.87^{b}	15.01	361.11 ± 2.54^{c}	4178.86 ± 42.95^{b}	23.31
HK	416.58 ± 1.41^{b}	4684.63 ± 160.61^{a}	21.12	404.22 ± 2.04^{a}	4557.16 ± 43.10^{a}	29.68
NB	425.48 ± 1.53^{a}	4852.08 ± 130.68^{a}	23.84	408.22 ± 2.99^{a}	4701.66 ± 79.66^{a}	31.84
P	4.92×10^{-9} **	1.28×10^{-10} **	5.92×10^{-3} **	1.41×10^{-8} **	5.72×10 −9**	4.23×10 −3**

Note: Data in the table are mean ± standard deviation. Different letters in the same column represent significant differences between different treatments at the 0.05 level (Duncan's method). ** indicates that there is a very significant correlation between experimental factors and results ($P < 0.01$).

Table 6: Expenditure, gross income, and net income after applying different soil modifiers.

										¥·ha^{-1}
Year	Soil modifier	Upfront costs							Gross income	Net income
		Seed	Soil modifier	Rent	Farm management	Chemical fertilizers	Extensions	Farm machinery		
2019	CK	300	0	1500	1000	750	3550	750	11085.66	6785.66
	MS	300	150	1500	1000	750	3700	750	12835.29	8285.29
	YK	300	250	1500	1000	750	3850	750	12855.21	8355.21
	HA	300	225	1500	1000	750	3775	750	13042.65	8517.65
	HK	300	1050	1500	1000	750	4600	750	14053.89	8953.89
	NB	300	3000	1500	1000	750	6550	750	14556.24	7256.24
2020	CK	300	0	1500	1000	750	3550	750	9613.74	5313.74
	MS	300	150	1500	1000	750	3700	750	11484.99	6934.99
	YK	300	300	1500	1000	750	3850	750	11534.85	7034.85
	HA	300	225	1500	1000	750	3775	750	12536.55	8011.55
	HK	300	600	1500	1000	750	4150	750	13671.48	8571.48
	NB	300	3000	1500	1000	750	6550	750	14104.95	6804.95

enhance soil water-holding capacity and effectively improve the water content. This showed consistency with our current findings. In this study, application soil modifiers significantly increased soil profile water content compared with CK (Figure 4). This is because the application of soil modifiers can increase the soil water-holding capacity. This could account for three possibilities. On the one hand, in terms of soil modifiers' molecular structure, soil modifier is a polymer with a great number of peptide bonds and hydrophilic groups. Such property enables it to facilitate its cross-link with soil moisture and absorb a large amount of water accordingly [29]. On the other hand, because of the difference sowing time. Studies have shown that sowing time has a significant effect on crop yield and nutrient absorption [30]. Moreover, the instability of continuous perennial and long-term precipitation in semiarid areas affects the stability of soil profile moisture content [28]. Soil modifiers stimulated the formation of soil aggregates and improved their stability. Soil aggregates could adjust soil moisture [29], as well as effectively store irrigation water and reduce soil water loss through evaporation [26].

4.2. Effects of Different Soil Modifiers on Salt Content and Salt Distribution of Maize Field. The application of soil modifiers to saline-alkali soils has aroused wide public concern and has been considered to be a good way to improve saline-alkali soil, in the past decades. The addition of soil modifiers to saline soil can improve its physical properties and salt content. The application of soil modifiers led to different changes in soil profile water, salt, and nutrients [16, 20, 26, 28, 30]. As an important indicator to measure the improvement effect of saline-alkali soil, soil salt content can better reflect the fertility characteristics and water permeability [31, 32]. The consequences showed the addition of five soil modifiers could decrease soil salt content, and the data in Figures 5 and 6 and Table 3 support our research. This shows consistency with the findings of previous researches that supported the significant decrease of soil salt caused by soil modifiers [29, 33–35]. The results reported by Pang et al. indicated that when the straw application amount of 3,600 kg/hm^2 was applied after MS, the comprehensive improvement effect on the structure, salinity, and other physical and chemical properties of coastal saline-alkali soil was relatively obvious. Dietrich found that the application of HA can effectively inhibit the increase of water-soluble K^+, Ca^{2+}, Mg^{2+}, and other base ions in the soil, thus reducing the electrical conductivity of the soil [34]. The application of HK soil modifier can increase the desalination rate of soil, and appropriate deep application could effectively improve the improvement effect of saline-alkali soil [29]. NB is beneficial to soil salt leaching under brackish rotation irrigation, and the desalination rate and the desalination zone depth coefficient are increased by 9.1%-15.0% and 1.1%-7.5%, respectively [35].

4.3. Effects of Different Soil Modifiers on Maize Growth, Leaf Photosynthetic Characteristics of Maize, and Yield. The maize growth of crop and yield increased strikingly in adding soil modifiers in soils, which is similar to previous research [16, 20, 28, 36]. Yang et al. also argued significant enhancement of maize growth and yield by soil modifier [26]. Moreover, Chen et al. showed that soil modifiers could improve drought-resistant of crop seedlings by adjusting soil moisture [20]. In this study, maize growth of crop and yield were affected by soil modifiers and obvious differences with different soil modifiers. The application of soil modifiers can promote crop growth and achieve higher yields. Based on the application of traditional soil modifiers, we introduced a new soil modifier. The new soil modifier used in this study has greater potential than the traditional soil modifier in promoting crop growth, improving crop yield. The data in Figure 4 and Tables 4 and 5 support these hypotheses. For example, in 2019 and 2020, maize yield increased by 13.63%-31.84%, and yield increases by NB>HK>HA>YK>MS. Studies from other regions have shown that applying soil modifiers can further crop growth and enhance crop yield than CK. This might be because of the following mechanisms. On one hand, soil modifiers enhanced soil water-holding capacity and hence promote increasing water use efficiency, crop growth, and crop yield [37]. On the other hand, MS and NB function in terms of storing, water availability improvement for crops, and thus the enhancement of crop growth and crop yield [20, 38]. The results reported by Nakayama et al. and Körner et al. indicated that the stomatal density decreased, stomatal and conductance (*Gs*) and the intercellular CO_2 concentration (*Ci*) decreased, ultimately leading to the decrease of net photosynthetic rate (*Pn)* [39, 40]. The results of this study also showed that NaCl stress restricted the growth and development process of maize, which was embodied in the reduction of plant biomass and the decrease of the net photosynthetic rate (*Pn)* the decreased. According the experimental, the result showed the application of soil modifiers had a significant impact on the photosynthetic characteristics of maize leaves.

In the process of decomposition, straw can absorb and use mineral elements in the soil to increase the soil organic matter and thus enhance the growth and yield of the crop [33]. NB can alleviate salt stress, and a high dose of NB can reduce the lethal effect of salt on crops [41]. The application of HK can improve maize crop growth and significantly increase maize yield [26]. Finally, soil modifiers promoted the formation of soil aggregates and increased the ability of nutrient adsorption, therefore enhancing crop yield. Application of HA had positive effects on the growth and appearance of crops under salt stress [42, 43]. Application of NB could promote the growth of common bean with higher Na^+ adsorption capacity [35]. These results are consistent with the experimental results in this experiment.

4.4. Appropriate Soil Modifier Application Strategy. From the viewpoint of agriculture production, we were hopeful in improving secondary saline-alkali soils with fewer soil modifiers to produce more, that is, achieving higher economic benefits. The results in this present study showed that applying soil modifiers can provide economic benefits than CK. The income increased 6.48%-38.01%, respectively, HK>HA>YK>MS>NB. According to analyzing the production of soil modifier application, we found that the highest net profit was achieved when HK application rate was 26.2 kg/ha^{-1}. Similarly, Yang et al.'s research reported that the highest crop yield was obtained when the recommended optimal HK application rate was 35 kg/ha^{-1} [26]. When it comes to economic benefits, the farmers showed more interest in the achievement of the largest net profit. Therefore, this study recommends that 26.2 kg/ha^{-1} might be an appropriate soil modifier application rate, which is beneficial to the improvement of crop growth as well as economic benefit in secondary saline-alkali soils of Northwest China.

5. Conclusion

Based on the application of traditional saline-alkali soil improvement, this study put forward a method of applying soil conditioning agents (soil conditioning agents: MS, HA, YK, HK, and NB) to reduce the impact of soil salt accumulation on typical crops in the Loess Plateau and improve soil saline-alkali. Compared with that of CK, the application of soil modifiers can increase soil water holding capacity, reduce soil profile salt content, and reduce salt accumulation, and the trend of desalination rate in 2019 and 2020 showed consistency, of which the increase is 71.57% and 46.02%, respectively. The average yield increases of the maize applied MS, YK, HA, HK, and NB were respectively13.63%, 13.76%, 15.09%, 21.12%, and 23.84% in 2019 and 18.42%, 16.65%, 23.31%, 29.68%, and 31.84% in 2020. The rank of the net income of maize with five soil modifiers shows as HK>HA>YK>MS>NB>CK. Therefore, applying soil modifiers as an economic and environmentally friendly soil remediation method can effectively improve the saline-alkali soil and promote the increase of yield and income.

Data Availability

The data that supports the findings of this study are available in this article.

Conflicts of Interest

The authors declare no conflict of interest.

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