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Effect of Different Fertilization Measures on Soil Salinity and Nutrients in Salt-Affected Soils

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Abstract: Saline soil from the coast is a valuable resource that is readily available. It is also a valuable resource for reserving arable land. It has been demonstrated that adding organic fertilizers to salinized soils can effectively enhance them. However, since the improvement of saline soils cannot be achieved by a single measure, the effects of compound measures of organic fertilizers combined with mineral elements, humic acid, are significant and might be examined in depth. In order to explore the effects of various measures on the features of pH, electrical conductivity (EC), and nutrient changes in coastal salinized soils in Yancheng, Jiangsu Province, a ryegrass-alfalfa rotation with organic fertilizer as well as compound measures was designed. The findings indicated that the total nitrogen (TN) content of the soil increased and that all organic fertilizer composites decreased the electrical conductivity of the surface soil. However, the organic fertilizer with microbial fertilizer and humic acid was especially effective at regulating the pH and electrical conductivity of the surface soil during the time when salts were prone to accumulating. In conclusion, our findings point to new approaches to lowering salinity and boosting fertility in coastal saline soils: organic fertilizer with microbial fertilizers and humic acid, as well as organic fertilizer with Attapulgite clay.

Keywords: microbial fertilizer; humic acid; Attapulgite clay; soil fertility; soil salinity

1. Introduction

Inland arid and semiarid regions, as well as coastal regions, are the principal locations for saline soils. The Food and Agriculture Organization of the United Nations estimates that there are around 9.54 million hm^2 of saline soils in the world, which are widely dispersed throughout more than 100 nations and regions [1]. A third of the world's saline soils are found in China, where their total area is estimated to be 3.69 million hm^2 [2]. The greatest barrier to producing agricultural land in coastal beach reclamation zones in salinized coastal areas is soil salinity. Saline soils have a high concentration of soluble salts, poor soil physicochemical characteristics, low soil enzyme activity, and sluggish nutrient release, which impacts plant nutrient absorption and upsets the nutrient uptake balance mechanism, lowering crop production and quality [3–5]. Different technical methods, including physical, hydrological, chemical, biological, and integrated remediation strategies, can be used to regulate soil salinity.

Several research has been carried out on the management and improvement of saline soils, including chemical, engineering, biological and integrated measures. Among these, biochemical measures involving the application of organic matter such as farmyard manure, straw and grey manure are generally considered to be the most economical and effective measures, which can increase soil porosity, reduce salt accumulation and mitigate salt damage, and have a significant impact on the management of saline soils [6–9]. As the long-term application of organic fertilizers can lead to the accumulation of soil salts, some organic materials are selected to improve the physical and chemical properties of saline soils by compounding with organic fertilizers. The Attapulgite clay

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(ATP) is rod-shaped and fibrous, with pores running through the layers and a concave-convex appearance. It has a large specific surface area and high thermal stability, showing good adsorption and ion exchange properties [10,11]. Slow-release fertilizer with attapulgite clay were used as the core material for slow release and water retention [12]. It has been established that attapulgite clay reduced soluble Na ions in soil via electrostatic attraction and cation exchange [13]. Polyacrylamide (PAM) has been demonstrated to improve soil structure, water content, pH, and organic matter stability when combined with other amendments [14]. Humic acid is the predominant component of soil organic matter and is a type of brown or black amorphous macromolecular colloidal complex generated following complex modifications in plant and animal wastes [15]. According to several investigations, humic acid combined with inorganic fertilizers lowered soil pH in coastal saline soils [16]. Bio-fertilizers have been demonstrated to improve soil physical and chemical qualities [17]. However, the effect of a single measure on improving saline soil is always limited. Comprehensive measures should have more advantages in improving coastal saline soil. Thus we conducted a one-year field trial of organic fertilizers in combination with multiple soil amendments in Jiangsu Province to investigate the synergistic effects of various amendment materials and organic fertilizers on coastal saline soils, and provide technical support for the improvement of coastal saline soil.

2. Materials and methods

2.1. Overview of the study site

The field experiment was set in the Dafeng District of Yancheng City, Jiangsu Province, China. The climate of the research region is subtropical, influenced by transitional, oceanic, and monsoon winds, with significant seasonal temperature and rainfall changes. The area's average year-round temperature is 14.4°C, with 1066.7 millimeters of precipitation, almost 70% of which falls between June and September, and 2214.4 hours of sunlight. Figure 1 depicted an overview map of the research area. Table 1 displayed the basic soil parameters in the study region. Figure 2 depicted Dafeng's precipitation and mean temperature from November 2020 to December 2021. Precipitation and average temperature data were obtained from the website : https://www.tianqi24.com/ .

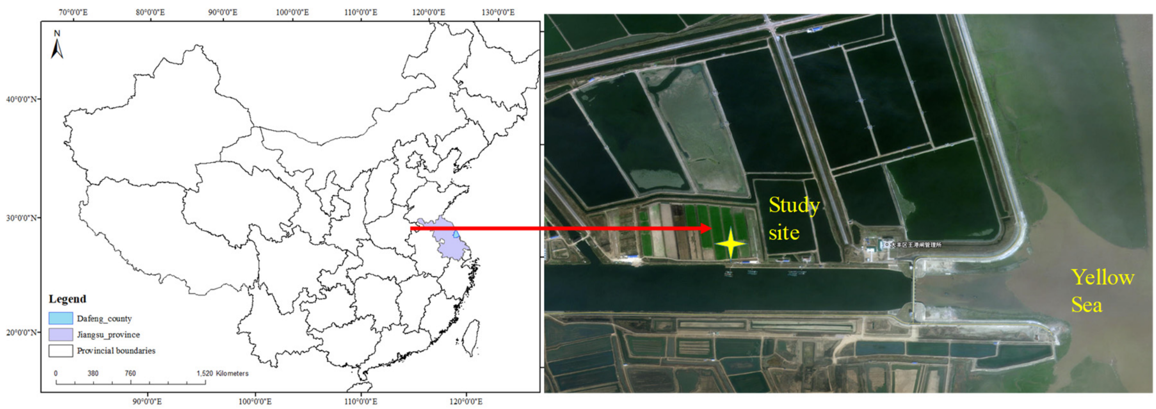

Figure 1. Overview map of the study area.

Table 1. Basic properties of the original topsoil (0–20 cm) used for the experiment.

	pH	EC(μS/cm)	SOM(%)	TN(g/kg)
CK	8.54	844.40	0.63	0.50
CK0	8.46	567.03	0.59	0.37
N	8.43	1037.33	0.64	0.38
NA	8.29	1166.00	0.68	0.57
NF	8.21	898.77	0.73	0.52

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NP	8.44	774.53	1.05	0.58
NFE	8.43	861.63	0.79	0.64

Note(s): EC, electrical conductivity; SOM, organic matter content; TN, total nitrogen.

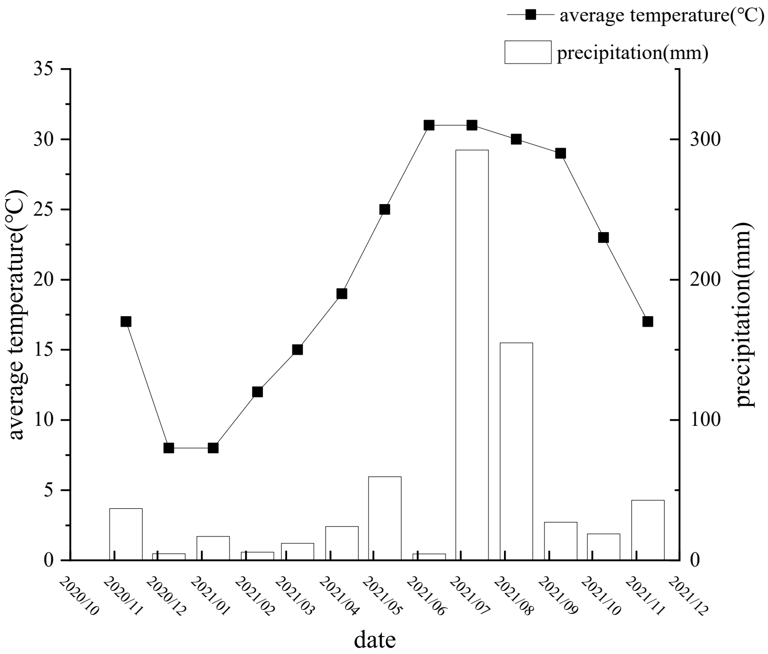

Figure 2. Monthly precipitation and average temperature in Dafeng.

2.2. Experimental treatments and sample collection

This experiment had seven treatments, each with three replications, for a total of 21 plots. The treatments were no fertilizer (CK), conventional fertilizer (CK0), organic fertilizer (N), organic fertilizer + Attapulgite clay treatment (NA), organic fertilizer + humic acid treatment (NF), organic fertilizer + PAM treatment (NP), organic fertilizer + humic acid + ETS biofertilizer treatment (NFE). All of the organic fertilizers used were commercial organic fertilizer. Ryegrass was planted from November 2020 to June 2021, while alfalfa was planted from June 2021 to November 2021. Nitrogen was sprayed at a rate of 225 kg/hm^2 for each planting season, and each treatment (except for the control treatment CK) was set up with a constant amount of nitrogen fertilizer after considering the nitrogen content of its material. Soil samples were taken from the 0-100 cm soil layer in November 2020, ryegrass was harvested and alfalfa was planted in June 2021, and soil samples were taken from the 0-100 cm soil layer in November 2021, and soil samples were taken from the 0-20 cm soil layer in the remaining months.

2.3. Soil testing methods

Soil electrical conductivity (EC) and pH were determined by a METTLER TOLEDO conductivity meter and a METTLER TOLEDO pH meter using 1:5 (w/v) soil: water suspensions. The organic matter (SOM) was oxidized by potassium dichromate and heated by an external heating method. The total nitrogen was determined using an element analyzer (DeChem-Tech Fully Automated Intermittent Chemistry Analyser, Germany).

2.4. Statistical analysis

Data were processed using SPSS version 26.0 and all data analyzed were presented as mean plus/minus standard deviation. Any significant differences between treatments were determined by one-way analysis of variance (ANOVA). Post-hoc tests were performed using Dunnett's method with a significance level of $p < 0.05$.

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3. Results and analysis

3.1. Effect of different fertilization measures on soil salinity

3.1.1. Effect of different fertilization measures on soil salinity in the 0-20 cm soil layer

The electrical conductivity in different periods could reflect the trend of soil salinity [18]. Although the initial salinity values in the 0-20 cm soil layer differed significantly between treatments, soil salinity tended to be similar in all treatments by November 2021. Treatments NFE, NP, NF, NA, and N all significantly reduced EC in the 0-20 cm soil layer compared to CK from November 2020 to November 2021, with treatment NA being the most successful, reducing EC by 56.6%, 39.3%, 64.9%, 124.3%, and 97.2%, respectively, compared to CK0. During this time period, all treatments showed an overall declining tendency, with the most pronounced decline from November 2020 to December 2020, with treatment NA showing the most pronounced decrease with the exception of a tiny increase in April 2021 (Figure 3). The soil EC values of all treatments were rapidly reduced in December 2020, and when compared to CK0, all composite treatments had better reduction efficiency, with treatment NA having the best reduction efficiency. With less precipitation from January 2021 to June 2021, the top layer of soil is more prone to salt formation, and treatment NFE has a salt suppression impact compared to CK0 and other treatments during this time period. In summary, all the treatments effectively declined soil EC in the 0-20cm layer except for NF by June 2021. During the process, NA showed the best reduction efficiency, followed by treatment NFE and N. From June 2021 to November 2021, salinity in all treatments was kept within a relatively safe range when crop growth was not affected by salts.

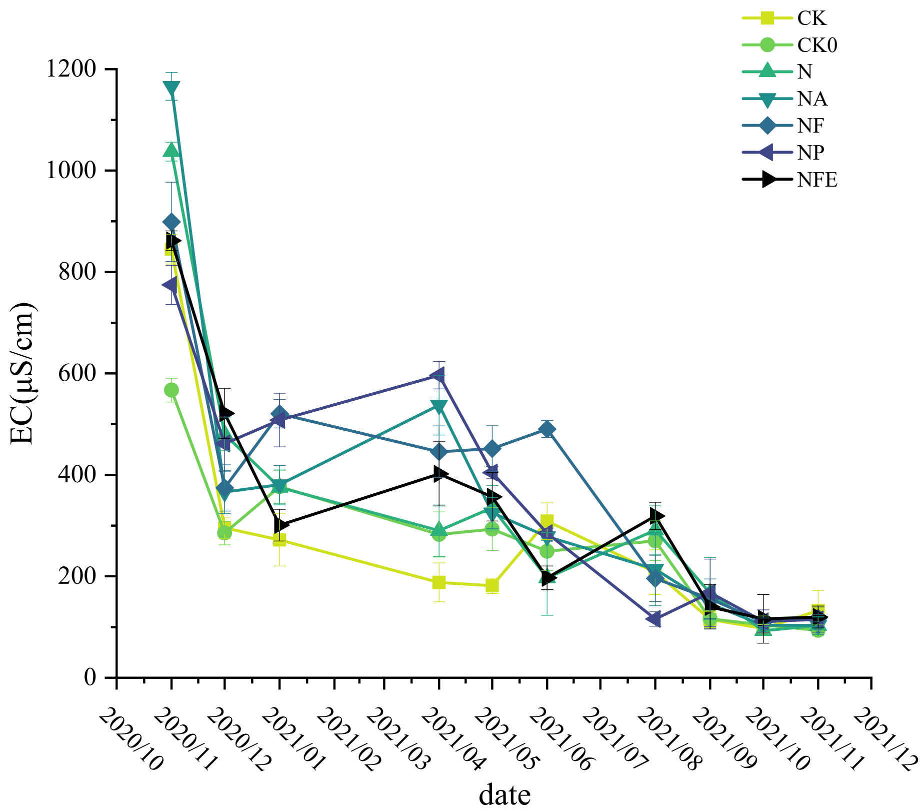

Figure 3. Effect of organic fertilizer compound treatments on EC in the 0-20 cm soil layer. Error bars indicate one standard deviation from the mean.

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3.1.2. Effect of different fertilization measures on soil salinity in the 20-40 cm soil layer

Treatments NP, NF, and N significantly reduced soil salt content in the 20-40 cm soil layer compared to CK0 from November 2020 to November 2021, with treatment N having the most significant effect. However, at the 20-40 cm soil layer, all treatments reduced soil salinity by November 2021 (Figure 4). When compared to CK0, treatments NP, NF, and N significantly lowered soil EC by 111.2%, 123.0%, and 235.6%, respectively. All treatments exhibited a considerable rise in soil salt content from November 2020 to December 2020, as salinity in the 0-20 cm soil layer decreased in December 2020, allowing salts to leach into the 20-40 cm soil layer. In June 2020, when precipitation was significantly lower than in May, treatment NF showed a decrease in May and an increase in June, which did not occur in the other treatments, indicating that treatment NF had no inhibitory effect on salinity during the period when salts were prone to accumulate. There was an overall declining trend in the EC values of the treated NFE from January 2021 to June 2021, demonstrating the effect of salt suppression. In summary, EC of all the treatments was controlled below 600 μS/cm except for NF treatment, where crop growth could not be affected by salts. From June 2021 to November 2021, the salinity of all the treatments was basically reduced to very low values.

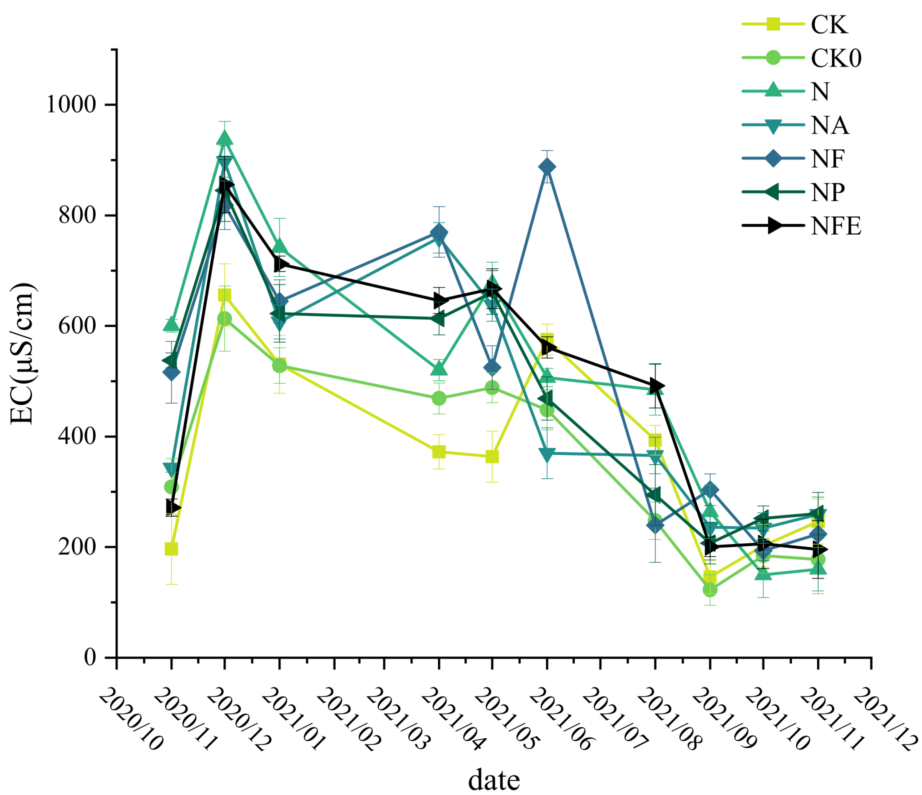

Figure 4. Effect of organic fertilizer complex treatments on EC in the 20-40 cm soil layer. Error bars indicate one standard deviation from the mean.

3.1.3. Effect of different fertilization measures on soil salt content in the 0-100 cm soil layer

Soil salinity in the 0-20 cm soil layer reduced significantly from November 2020 to November 2021, but salinity in the 80-100 cm soil layer rose in all cases. Although there were some differences in the initial values of soil salinity in each treatment's 0-100 cm soil layer, the distribution of soil salinity content was basically the same in November 2020 and June and November 2021. Soil EC in the 20-40 cm soil layer of each treatment in November 2020 had a significant decrease compared to the soil salinity content in the 0-20 cm soil layer, followed by a significant decrease in the soil salinity content in the 0-20 cm soil layer. Soil EC of 40-60 cm soil layer, 60-80 cm soil layer, and 80-100 cm soil layer fell more slowly. In June 2021, the soil EC in the 20-40 cm soil layer of each treatment was greater

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than that in the 0-20 cm soil layer, and then the soil salinity steadily declined as soil depth increased. Treatments NP, NA, and NFE had a gradual increase in salinity content in the 0-60 cm soil layer, while the soil salinity content in the 60-80 cm soil layer decreased. Treatments CK, CK0, N, and NF had a gradual increase in salinity content in the 0-80 cm soil layer and a decrease in salinity content in the 60-80 cm soil layer (Figure 5) . NF treatments were not effective in controlling soil salinity in the profile by June 2021, and the remaining treatments performed well in reducing salinity in soil layer of 0-40cm. By November 2021, soil salinity was leached to the deeper layer, and The salinity of the upper soils are all controlled in the lower values.

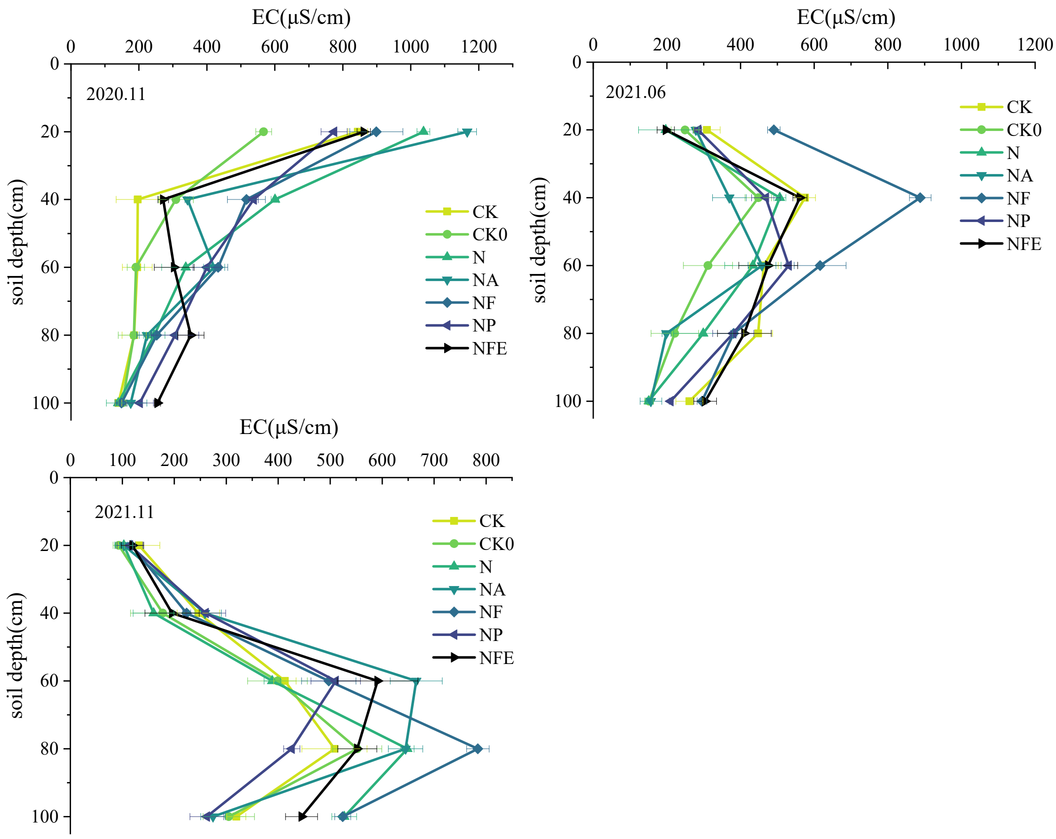

Figure 5. Effect of organic fertilizer compound treatment on EC in the 0-100 cm soil layer. Error bars indicate one standard deviation from the mean.

3.2. Effect of different fertilization practices on soil pH

3.2.1. Effect of different fertilizer application measures on pH in the 0-20 cm soil layer

The pH value of all treatments in the 0-20 cm soil layer increased slightly from November 2020 to November 2021, whereas treatment NA's pH increased dramatically. Throughout the trial period, the pH of all treatments fluctuated, but in September, October, and November 2021, the pH of all treatments decreased, then increased, and then decreased, and in October 2021, the pH of all treatments was over 9.00. The pH of treatments NFE, NP, and NA was considerably lower than CK0 from November 2020 to May 2021. Overall, the pH of treatments N, NP, and NFE increased less than that of the control treatment CK0. In December 2020, treatments N, NP, and NFE all exhibited a falling trend, while the remaining treatments showed a little increase (Table 2). Treatments NA, NF, NP, and NFE had considerably lower pH than CK0 from December 2020 to November 2021. Overall, all the treatments improved pH compared to the initial pH value but were still lower than the value of CKO treatment.

Table 2. Effect of different organic fertilizer compound treatments on soil pH in the 0-20 cm soil layer.

	Sampling date									
Treatment	2020.11	2020.12	2021.01	2021.04	2021.05	2021.06	2021.08	2021.09	2021.10	2021.11
CK	8.54±0.06a	8.85±0.08a	8.95±0.02a	9.42±0.04a	8.83±0.02a	9.15±0.05a	9.28±0.03b	8.96±0.01b	9.39±0.02a	8.64±0.03a
CK0	8.46±0.02b	8.68±0.08b	8.39±0.05c	8.6±0.04c	8.66±0.04bc	8.54±0.05c	9.37±0.02a	8.85±0.04c	9.38±0.04a	8.65±0.03a
N	8.43±0.04b	8.37±0.05d	8.73±0.02b	8.83±0.03b	8.57±0.11cd	8.85±0.05b	9.05±0.05d	8.72±0.03d	9.42±0.04a	8.52±0.07b
NA	8.29±0.08c	8.15±0.03e	8.32±0.04d	8.52±0.02c	8.40±0.02e	8.56±0.03c	9.10±0.02c	8.98±0.03b	9.15±0.03b	8.61±0.02a
NF	8.21±0.04c	8.55±0.01c	8.25±0.02e	8.28±0.02d	8.71±0.03b	8.86±0.03b	8.67±0.01e	8.65±0.02e	9.38±0.05a	8.47±0.02b
NP	8.44±0.02b	8.06±0.03e	8.16±0.02f	8.29±0.02d	8.55±0.04d	8.51±0.04c	9.38±0.01a	9.05±0.02a	9.21±0.04b	8.46±0.04b
NFE	8.43±0.04b	8.14±0.05e	8.27±0.04de	8.57±0.11c	7.99±0.07f	8.86±0.02b	9.07±0.02cd	8.83±0.02c	9.00±0.04c	8.52±0.03b

Note: Different letters in the same column indicate significant differences between the two groups (p<0.0 5).

3.2.2. Effect of different fertilizer applications on pH in the 20-40 soil layer

Except for the CK, the pH of the 20-40 cm soil layer increased over the experiment, and the increase in pH for treatments N, NA, NF, NP, and NFE was more than that of CK0, with treatment NF showing the biggest increase in pH, followed by treatment N. In December 2020, the pH of all treatments decreased considerably. Except for January and April 2021, the pH of treatment NF was significantly lower than CK0 from October 2020 to October 2021, and the pH of treatment NP was significantly lower than CK0 (Table 3) . Overall, all the treatments improved pH compared to the initial pH value but were still lower than the value of CKO treatment. By November 2021, pH of treatment NP was the lowest, followed by NA and NFE. To summarize, treatment NP, NA and NFE performed better in terms of soil pH reduction in the 20-40 cm soil layer.

Table 3. Effect of different organic fertilizer compound treatments on soil pH in the 20-40 cm soil layer.

	Sampling date									
Treatment	2020.11	2020.12	2021.01	2021.04	2021.05	2021.06	2021.08	2021.09	2021.10	2021.11
CK	9.32±0.03a	8.37±0.03b	8.64±0.05a	9.17±0.04a	8.88±0.02a	8.72±0.01a	9.26±0.02a	9.57±0.06a	9.14±0.03bc	9.27±0.01a
CK0	8.94±0.02b	8.50±0.04a	8.29±0.01cd	8.23±0.04e	8.68±0.03b	8.53±0.05b	9.29±0.04a	9.28±0.03b	9.18±0.02b	9.07±0.05b
N	8.45±0.04d	8.23±0.01c	8.25±0.02de	8.74±0.03b	8.33±0.06f	8.73±0.05a	8.21±0.04c	8.74±0.03e	8.94±0.02d	9.08±0.01b

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NA	*8.39±0.04e*	*7.96±0.03e*	*8.47±0.03b*	*8.54±0.03c*	*8.56±0.01c*	*8.43±0.03c*	*9.16±0.02b*	*9.23±0.04b*	*9.36±0.07a*	*8.92±0.07c*
NF	*8.41±0.04de*	*8.16±0.02d*	*8.21±0.04e*	*8.05±0.01f*	*8.41±0.03de*	*8.45±0.06c*	*9.17±0.05b*	*8.75±0.04e*	*9.09±0.05c*	*9.11±0.0b*
NP	*8.36±0.03e*	*8.16±0.03d*	*8.35±0.04c*	*8.43±0.03d*	*8.35±0.02ef*	*8.25±0.05d*	*9.11±0.01b*	*8.95±0.02d*	*8.74±0.02e*	*8.74±0.03d*
NFE	*8.70±0.04c*	*8.13±0.03d*	*8.32±0.02c*	*8.45±0.05d*	*8.44±0.04d*	*8.44±0.03c*	*9.15±0.04b*	*9.15±0.03c*	*9.09±0.04c*	*9.04±0.05b*

Note (S): Different letters in the same column indicate significant differences between the two groups (p<0.0 5).

3.2.3. Effect of different fertilization measures on soil pH of 0-100 cm soil layer

The initial pH values in the 0-100 cm soil layer varied significantly between the treatments, with treatments NF, NA, and N showing a similar trend of increasing pH as the soil layer became deeper. Treatments of NFE, CK0, and CK showed a similar trend of increasing pH in the 20-40 cm soil layer and decreasing pH as the soil layer became deeper from 40 to 100 cm. Treatment NP showed a 20-40 cm soil layer decreased, and after 40 cm soil layer, the pH in treatments NP was lower. For treatments combined with compound treatment of organic fertilizer, the pH in the 0-80 cm soil layer was less than CK0, whereas the pH in the 80-100 cm soil layer was more than CK0. By June 2021, the trend of pH variation in different soil layers for all treatments was basically the same, with pH falling and then increasing as the soil layer got deeper. The pH values of treatments NA and NP were slightly higher than CK0 in the 80-100 cm soil layer but lower than CK0 in the 0-80 cm soil layer. Whereas pH values of treatments NF and NFE were higher than CK0 in the 0-20 cm soil layer but lower than CK0 in the 20-100 cm soil layer. In November 2021, the pH in the 0-100 cm soil layer for treatments NA, NP, and NFE was less than CK0, with the exception of treatment NP in the 20-40 cm soil layer. In summary, compound treatments of NP, NA and NFE decreased soil pH in the 0-80 cm soil layer (Figure 6).

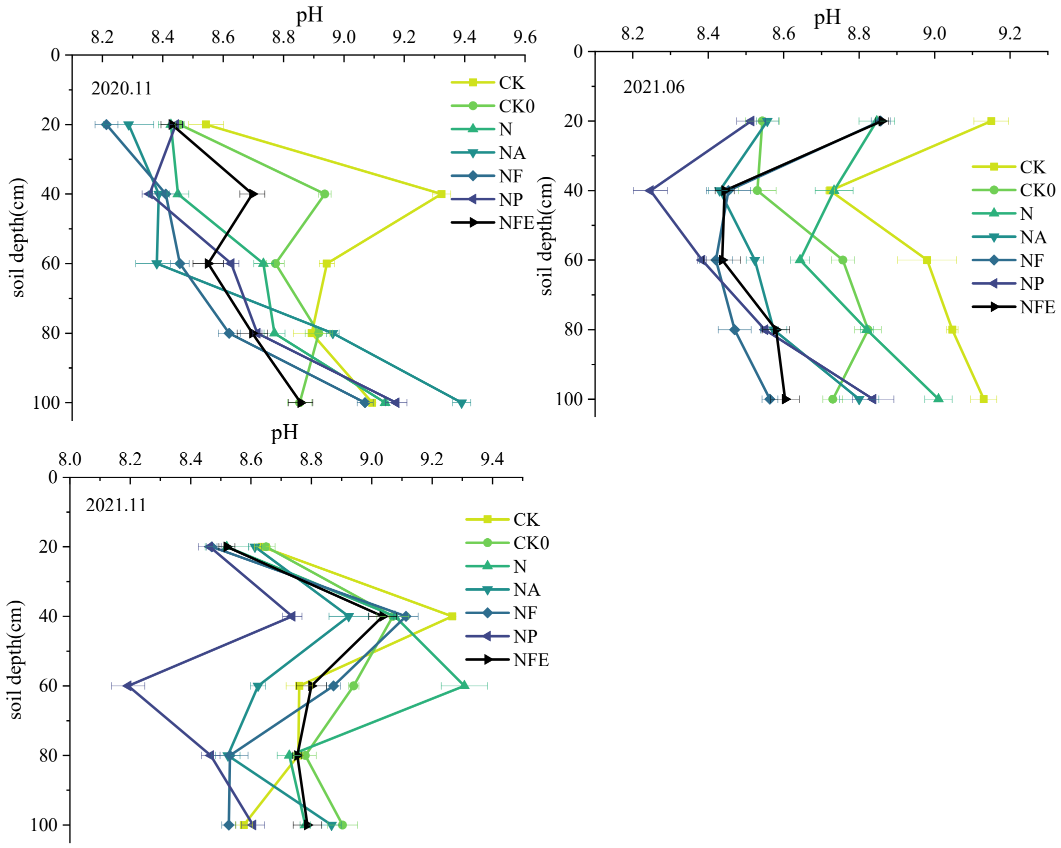

Figure 6. Effect of organic fertilizer compound treatment on pH in the 0-100 cm soil layer. Error lines indicate one standard deviation from the mean.

3.3. Effects of different fertilization practices on soil nutrients

3.3.1. Effect of different fertilizer application measures on soil organic matter

The initial value of soil organic matter（SOM） in all treatments had no significant difference except for treatments of NP and NFE. By November 2021, the SOM of treatments of NA, NF, and NFE was much greater than that of CK0, while the SOM of NP treatment was significantly lower. The SOM of treatments of NA and NF increased by 34.4% and 148.1% compared with that of CK0, respectively, while SOM of NFE treatment was lower (Figure 7). Compared to CK0, treatments NA, NF significantly increased soil SOM, while treatments N, NP decreased it, but the SOM of treatment NFE remained basically unchanged, ensuring the stability of the organic matter.

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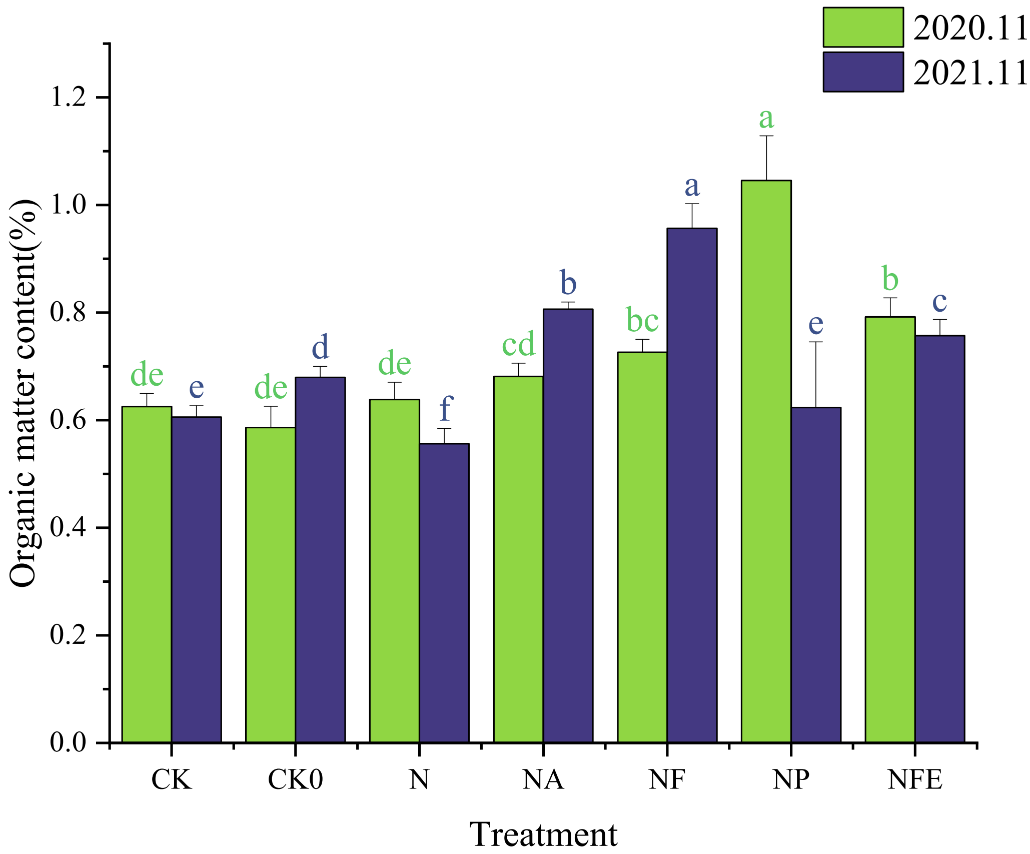

Figure 7. Effect of organic fertilizer compound treatments on the organic matter content of the 0-20 cm soil layer. Error bars indicate one standard deviation from the mean.

Note(s): the different colors represent various group. Different letters of the same color indicate significant differences between treatments ($p<0.05$).

3.3.2. Effect of different fertilization measures on soil total nitrogen

The pattern of change in SOM and TN content in the 0-20 cm soil layer was consistent across all treatments. In November 2021, soil TN content grew significantly in all treatments, and the increase in TN in all composite treatments was significantly greater than that of CK0, with treatment NA increasing significantly more than other treatments. Finally, the composite treatments were able to greatly enhance soil TN content, with the effect of increase being NA>NF>NFE>NP. (Figure 8).

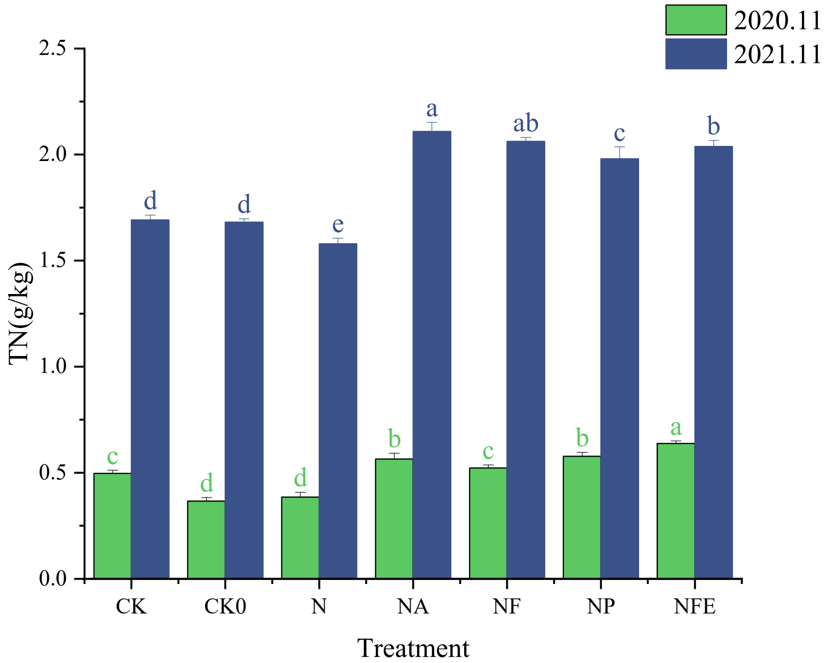

Figure 8. Effect of organic fertilizer complex treatments on the total nitrogen content of the 0-20 cm soil layer. Error bars indicate one standard deviation from the mean.

Note(s): the different colors represent various group. Different letters of the same color indicate significant differences between treatments ($p<0.05$).

4. Discussion

High salt concentrations can impede plant growth through nutritional imbalance, osmotic stress, and specific ion toxicity [19]. Soil salinity has a negative impact on crop yield and agricultural sustainability. Numerous studies have demonstrated that using organic fertilizers and chemical additions can not only reduce soil salinity but also increase saline soil fertility [20–22]. The current field experiment focused on how soil EC, pH, organic matter content, and total nitrogen content changed under the compound measures combined with organic fertilizer, humic acid and other materials. Our findings contributed to the increasing number of evidence indicating the interaction of organic fertilizers with chemical additions altered the characteristics of saline soils and soil nutrients.

4.1. Effect of different fertilizer applications on soil salt content and pH

In this study, organic fertilizer and its compound measures were effective in decreasing the salt content of soil 0-20 cm soil layer, with the organic fertilizer combined with attapulgite clay having the most noticeable reduction impact. Organic fertilizer compounded with PAM and humic acid reduces the salt content of the soil's 20-40 cm layer, however the effect of organic fertilizer compound treatment on reducing the salt content and pH of deeper soil layer was not obvious. Due to their excellent adsorption properties, Attapulgite Clay [13] have also been found to be a material for lowering soil salinity. In the current study, the influence of Au-bearing rods on soil salt content was only found in the 0-20 cm soil layer. In contrast, Attapulgite Clay can absorb Na^+ from the soil [13], lowering the salt concentration in the 0-20 cm soil layer considerably. Zhao [30] demonstrated that Attapulgite Clay will greatly increase soil pH, which is consistent with the current study's findings, most likely because Attapulgite Clay is alkaline and will significantly affect soil pH when applied to the soil, particularly in the cultivated layer.

According to research [23], the application of PAM can improve soil characteristics and decrease salinity. These findings are likely due to the fact that PAM not only improves soil surface particle cohesion, increases the content of soil aggregates >0.25 mm, improves soil stomatal structure and permeability, and inhibits the formation of soil crust [26], but it also allows salts to percolate downwards, reducing the salinity of the 0-40 cm soil layer. Liu [24] and Huang [25] discovered that humic acid can increase soil macroaggregates and reduce salinity in the soil tillage layer, which is consistent with the results of our experiment.

Humic acid lowered soil pH while increasing soil salinity [27–29], and soil EC of organic fertilizer with humic acid slightly increased and pH of the treatment declined in present study, which was similar to the results of previous study. However, when implemented together with biological fertilizer, the effect on EC and pH was changed, which was to reduce conductivity while regulating pH.

4.2. Effect of different fertilizer application measures on soil organic matter

Soil organic matter is an important component of soil fertility and one of the most important soil fertility indicators [31]. Studies have shown that adding humic acid to salt-affected soils can significantly reduce salt stress and improve plant growth by improving nutrient availability and water retention, enhancing soil structure, and increasing microbial bioactivity [32,33], and because humic acid is an important component of soil organic matter, the addition of humic acid in this study resulted in a significantly higher organic matter content of the soil. The use of Attapulgite Clay and organic fertilizer, on the other hand, can manage and fix nutrients in the soil. Although no research has been conducted to prove that Attapulgite Clay can increase soil organic matter, organic fertilizer compounded with Attapulgite Clay increased soil organic matter significantly in this study, and I believe that Attapulgite Clay can accelerate the release of nutrients from organic fertilizer and fix nutrients in the soil so that organic matter in the soil will be enhanced after ryegrass harvesting and alfalfa planting. Biofertilizer has been shown to improve soil nutrients and increase soil organic matter [34,35], but the effect was less pronounced in this study, likely due to an antagonistic effect between biofertilizer and humic acid, and the two could not increase soil organic matter when used together.

4.3. Effect of different fertilization measures on soil total nitrogen content

Total soil nitrogen is another significant nutritional indicator. It has been demonstrated that humic acid increases total soil nitrogen [28], which is compatible with the findings of our study. Attapulgite Clay treatment enhanced total soil N, and its application with organic material boosted total soil N considerably. The use of Attapulgite Clay increased soil agglomeration and caused it to form a protective coating, reducing contact between the soil surface and air and thereby reducing N loss [36]. This, I believe, is the primary reason for the increase in total N content of the soil caused by the application of organic fertilizer including Attapulgite Clay. Organic fertilizer combined with microbial fertilizer and humic acid boosted total soil N in this experiment. Ma [37] found that biofertilizer had no discernible effect on total soil N, whereas some studies [31,32] found that biofertilizer could boost soil nutrients. I believe that biofertilizer with humic acid hastened the breakdown of organic matter, which increased soil nutrients and the overall soil N content, which is similar to the results of this study.

5. Conclusion

In the study area, the ryegrass-clover rotation system enhanced soil nutrients, and this experiment demonstrated that organic fertilizer and other techniques may reduce the salinity of coastal saline soils, but they were still dependent on precipitation. Thus composite measures were effective in improving coastal saline soil due to the abundant precipitation in coastal region of Jiangsu Province. Organic fertilizer with Attapulgite Clay can reduce the salinity of coastal saline soil and increase soil nutrients and controlling soil pH. Humic acid and microbial fertilizer implementation together with organic fertilizer can enhance soil total nitrogen and organic matter while lowering soil salinity and controlling the pH of the soil surface layer. In conclusion, compound measures of NA

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and NFE were two suggested options that can regulate the salinity and pH of coastal saline soil while also improving soil fertility in the coastal saline soil.

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