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Residue Mulching Alleviates Coastal Salt Accumulation and Stimulates Post-Fallow Crop Biomass under a Fallow–Maize (*Zea mays* L.) Rotation System

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Abstract: Fallow, a field where living plants are unplanted for a period, is continually implemented to accumulate moisture for the upcoming cultivation. However, there are less studies on the fallow strategies in one-crop-per-annum cropping system for coastal saline soils. In this study, 2-year "fallow + maize (*Zea mays* L.)" rotation experiments were carried out from 2016 to 2018 to assess how the mulching determine post-fallow soil moisture, salt distribution, and crop performance. Three treatments were designed, i.e., traditional cultivation without residue retention (TT), traditional tillage with total straw mulching during fallow (TT + SM), and no-till cultivation combined fallow mulching (NT + SM). After 2 years of fallow mulching with maize rotation, TT + SM reduced soil electrical conductivity (EC) and total salt of the upper 30 cm soil profile by 22.9% and 25.4% ($p = 0.05$), respectively, compared with the TT treatment. The results also indicate an improvement in volumetric soil water content (SWC) by 10.3%, soil organic matter (SOM) by 17.8%, and ultimately grain yield by 11.3% ($p = 0.05$) under the TT + SM treatment. Fallow mulching is recommended as an acceptable way to protect soil health in coastal fresh-starved or rain-fed farming practice.

Keywords: coastal salt-affected soil; one-crop-per-annum cropping; fallow mulching; salt accumulation; crop growing

Citation: Zhang, Y.; Yuan, W.; Han, L. Residue Mulching Alleviates Coastal Salt Accumulation and Stimulates Post-Fallow Crop Biomass under a Fallow–Maize (*Zea mays* L.) Rotation System. *Agriculture* **2022**, *12*, 509. https://doi.org/10.3390/agriculture12040509

Academic Editors: Chengfang Li and Lijin Guo

Received: 26 February 2022
Accepted: 31 March 2022
Published: 3 April 2022

1. Introduction

Soil salinization is a process during which the salt in the deep soil and groundwater rises to the surface via evaporation, and then accumulates in the topsoil. Salt accumulation has been one of the most severe ecological environmental problems that restricts the agricultural sustainable development in arid and semi-arid areas [1–4]. Currently in China, principally distributed in the northeast, northwest, and coastal areas, more than 36 million hectare farmlands are suffering from salinity, accounting for approximately 4.9% of the whole available lands [5–7].

Stimulating grain yield in coastal farmlands is a vital part of ensuring food security. Focusing on the special climate and hydrological conditions, soil desalination for coastal areas was conducted mainly by following three aspects, i.e., salt leaching, capillary water blocking, and biological desalination [8–10]. However, it is of great importance to introduce different ways to minimize salt constraints and expanding agricultural output. Generally, coastal croplands are vulnerable to anthropogenic activities and climatic changes. Especially in the coastline of Bohai bay, east China, the fluctuation in sea level and the excessive consumption of groundwater will inevitably induce the invasion from seawater. Reasons for the severe salt stress primarily come from the following three aspects [11,12]. Firstly, year-round intrusion by seawater leads to excessively groundwater salinity concentration. Secondly, mainly concentrated in summer, the precipitation in this region is uneven throughout the four seasons as affected by the oceanic climate. Thirdly, from autumn to next spring, salt accumulates upward into the topsoil via evaporation, a result from the monsoon and drought. Therefore, "fallow + maize (*Zea mays* L.)" rotation cultivation has been applied for decades in this region, and the local farmers tend to cultivate summer maize due to the scarce fresh water and fallow in the post season.

Fallow, a period during which no living plants are grown, is frequently utilized to collect moisture and nutrition for subsequent cultivation [13]. Fallow is feasible to solve environmental deterioration through the self-recovery of the barren or low-yield lands. It was reported that fallow practice had advantages in improving soil hardening, desertification, enhancing biodiversity, and thereby increasing grain production and ensuring food security [14,15]. Overall, fallow is a feasible practice in arid and part of subhumid regions, when the accessible rainfall during cropping season is less than that required for expected yield [16,17]. However, fallow inevitably incurs shrinking output due to the extended time without cash crop cover.

Straw mulching, soil cover with crop residues, has been well confirmed to have positive influences on soil water and heat redistribution, soil physicochemical properties and nutrient, and ultimately facilitate crop performance [18–21]. In addition, straw mulching also produced the expected effect in salt-affected soils. Wang et al. [22] found that water evaporation decreased significantly, while the saline soil was covered. Moreover, cotton straw was demonstrated to have a positive effect on soil fertility and crop yields [23]. Based on the previous studies, straw, as a by-product from farmland crops, has great potential in improving the soil environment, especially because it is available and easy to apply. More importantly, Yang [24] indicated that fallow rotation under straw mulching was beneficial to improve soil structure, which provides a feasible reference for the exploration on the "fallow + summer maize" rotation.

Therefore, this study aims to achieve a fallow–maize rotation crop system with severe salt accumulation and insufficient freshwater, and we attempt to introduce reasonable fallow managements, as well as to survey appropriate agronomic solutions for coastal salt-affected croplands. We hypothesized that, if maize straw mulching is beneficial to reduce the upward salt accumulation during fallow, the subsequent cropping season would obtain better water and salt conditions. In this study, a 2-year fallow–maize rotation cultivation was carried out, and during the fallow period, the field was covered with maize straw after harvest to ascertain how they impact the salt movement and crop growth. Before each cropping season, soil electrical conductivity (EC), total salt, soil organic matter (SOM), bulk density, and volumetric soil water content (SWC) were measured, as well as the relevant grain yield, to investigate the comprehensive response in comparison to traditional management. Accordingly, the objective of this study was to assess the response of soil moisture distribution and crop performance to fallow straw mulching, and to provide a reproducible approach to cultivate coastal saline croplands.

2. Materials and Methods

2.1. Experimental Site and Soil

From May 2016 to September 2018, fallow combined with summer maize rotation experiments were conducted in the Binhai district, Tianjin city, China (38°46′ N, 117°13′ E, Figure 1). The climate is semi-humid and monsoons with 211 frost-free days and 12.3 °C of annual average temperature. The 570 mm annual precipitation is fluctuant and imbalanced, mainly (>70%) concentrated from June to September. The annual evaporation is about 1800 mm, and the evaporation–precipitation ratio exceeds 3:1.

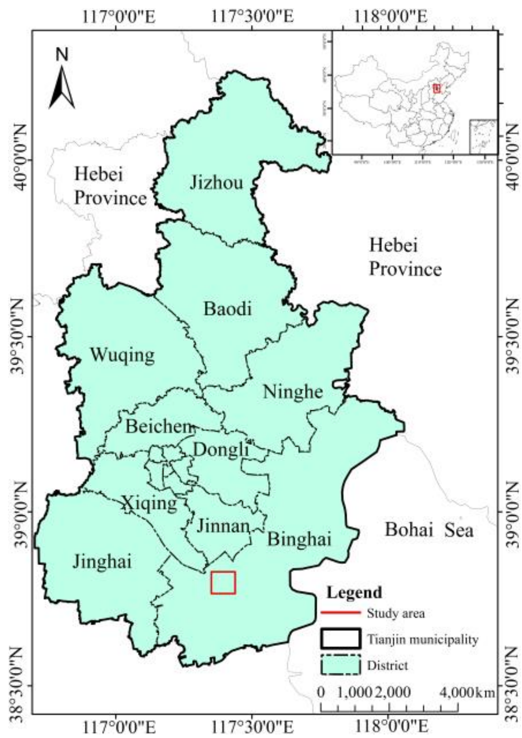

Figure 1. Location of the experimental site.

Before the initiation of field experiments, the soil was defined as solonchak, with 2.67 mg kg^{-1} of sodium, 7.08 g kg^{-1} of salt content, 10.4 g kg^{-1} of SOM, 64.5 mg kg^{-1} of alkaline-hydrolysable nitrogen, 31.4 mg kg^{-1} of available phosphorus (by Olsen), and 63.2 mg kg^{-1} of available potassium. The soil texture was silty clay loam, according to the USDA classification. The physical properties of the 0–30 cm profile prior to experiments are shown in Table 1.

Table 1. Soil physical properties of the 0–30 cm profile before experiments.

Items	Mean Value	Unit
Sand (0.05~2 mm)	10.6	%
Silt (0.002~0.05 mm)	61.0	%
Clay (<0.002 mm)	28.4	%
Soil bulk density	1.39	g cm^{-3}
Field capacity (by weight)	28.4	%
Total porosity	46.5	%

2.2. Experimental Design

Prior to 2016, the site was farmed traditionally for decades with summer maize cultivation. In this study, the whole sites were ploughed to eliminate the existing plough pan in early June. Then, the seedbed was renovated by rotary harrowing to a depth of 0.15 m and smoothing before planting. In late September, maize harvest and total stubble removing were executed manually, according to traditional tillage management. This research was performed after maize harvest, and three treatments were designed in this study: (1) TT, traditional tillage for maize cultivation with no straw being returned to the field after maize harvest, as the control group; (2) TT + SM, traditional tillage for maize cultivation with 100% fallow straw mulching from harvest to planting in the next year; and (3) NT + SM, 100% fallow straw mulching without tillage. The three treatments were applied to a randomized design with three replicates. The plots were ridged against cross contamination, and each was 36 m long and 15 m wide.

Table 2 describes the cultivated details of the fallow–maize rotation. In late September 2016, dry maize stubble was equally supplied in each mulch-treated plot at 4000 kg ha^{-1} for the TT + SM and NT + SM treatments. In late September 2017, the residues harvested from the previous cropping season were all retained (i.e., 100% straw retention) in each site by mulching. For the sowing procedure of the NT + SM treatment, the maize was planted directly without seedbed renovation.

Table 2. Cropping schedules for the fallow–maize rotation system. The precipitation was calculated during the cropping season or fallow period, i.e., from maize planting to harvest and from maize harvest to the next year planting, respectively).

Rotation Design	Start or Planting Date	End or Harvest Date	Precipitation (mm)
Prior to experiment		Late September 2016	
Fallow	Late September 2016	Early June 2017	105.1
Maize cropping	Early June 2017	Late September 2017	350.3
Fallow	Late September 2017	Early June 2018	162.9
Maize cropping	Early June 2018	Late September 2018	433.3

During each in-season cultivation, a coincident cropping method was applied in accordance with the local farming practice. A no-till maize seeder was applied to execute sowing and fertilizing simultaneously. In detail, the experimental cultivar was Zhengdan958 with a row spacing of 60 cm and 28 cm seed spacing in a row, which was sown on 9 June 2017 and harvested on 29 September and again sown on 6 June 2018 and harvested on 27 September. The fertilizer was incorporated at a rate of 45 kg hm^{-2} of N, 45 kg hm^{-2} of P_2O_5, and 40 kg hm^{-2} of K_2O, while sowing. In addition, 40 kg hm^{-2} of N was supplied as topdressing at the jointing stage. Plant protection, such as weeds, insect pests, and diseases. was performed when needed in accordance with the local agronomic specifications.

2.3. Sampling and Measurement

Soil samples were collected at the end of fallow period, i.e., early June of 2017 and 2018, before the seedbed renovation for maize sowing. The disturbed samples were air dried, then pulverized and screened for chemical properties measurements. Soil EC was measured using the soil water suspension (1:5, w/v) by an EC meter. SOM was determined under the dichromate oxidation method by Liu et al. [25]. Total salt storage to the calculated soil profile was measured as the mass per unit area, as described by [26]:

$$\text{Total salt} = 10\sum \rho_{bi}\, s_i\, z_i, \tag{1}$$

where ρ_{bi} is the soil bulk density of the i soil layer; in g cm^{-3}; s_i is the soil salt content of the i soil layer, in g kg^{-1}; and z_i is the thickness of the i soil layer, in cm.

The undisturbed soil cores were taken before the seedbed renovation using the constant volume cutting ring. The volumetric SWC investigation was performed using the oven drying method, as described by He et al. [27]:

$$b_v = b_m \times (\rho_b/\rho_w), \tag{2}$$

where b_v expresses the volumetric SWC, in cm^3 cm^{-3}; b_m is the gravimetric SWC, in g g^{-1}; ρ_b and ρ_w are the soil bulk density and water density, respectively, in g cm^{-3}.

Plant samples were collected at maturity stage from five randomly selected plants in each plot. Root samples were collected within a 0.15 × 0.15 m square, and to a depth of 0.40 m. Adhered soil particles and unrelated impurities were removed by running tap water, and then the roots were air dried and oven dried at 70 °C unto constant weight to provide the root biomass. Three 5 m long rows were randomly selected under different treatment to determine maize yields. The grain yield was adjusted to 12.0% moisture content.

2.4. Statistical Analyses

The mean values were calculated for each measurement, and analysis of variance (ANOVA) was performed to evaluate the effect of different treatments on the variables with SPSS software (International Business Machines Corporation, New York, NY, USA). Normality and homoscedasticity were tested for original data before the ANOVA test. If the homogeneity did not show, the original data were classified to conform to the requirement. Multiple comparisons were conducted based on the least significant difference test (LSD) at a 5% level of probability ($p = 0.05$).

3. Results

3.1. Soil EC

Figure 2 compared mean soil EC in the top 30 cm soil layer at the end of the fallow period, i.e., before the seedbed renovation for maize sowing. In the entire 2-year observation, the TT treatment showed the highest values in soil EC in comparison with the TT + SM and NT + SM treatments ($p = 0.05$). The mean EC under the TT + SM treatment appeared to be the lowest, which showed a reduction by 9.8% in 2017 and 22.9% in 2018, in comparison to the TT treatment ($p = 0.05$). Additionally, despite the lack of a significant difference in 2017 (by 7.9%), the NT + SM treatment had a 12.6% significant improvement in EC, as compared to TT ($p = 0.05$).

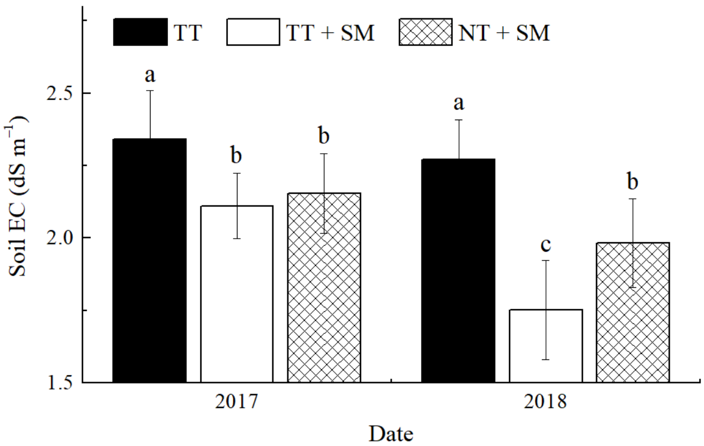

Figure 2. Mean soil electrical conductivity (EC) in the upper 30 cm profile for the TT, TT + SM, and NT + SM treatments. TT: traditional tillage for maize cultivation without straw return after maize harvest; TT + SM: traditional tillage with 100% straw mulching after harvest; NT + SM: no-till cultivation combined with 100% straw mulching. Data were measured at the end of fallow period, i.e., early June of 2017 and 2018 before maize sowing. Means in the same year followed by a different letter are significantly different ($p = 0.05$).

3.2. Total Salt

The total salt in the top 30 cm soil layer was calculated and is shown in Table 3, which reveals its similar tendency with that of soil EC. Compared with the TT treatment, total salt under the TT + SM treatment significantly decreased by 11.3% in 2017 and 25.4% in 2018, respectively ($p = 0.05$). The NT + SM treatment showed an 8.9–13.2% decrease in total salt ($p = 0.05$). Additionally, the total salt under the TT + SM treatment tended to be lower, and a significant decrease was observed in 2018 by 14.0%, when compared with the NT + SM treatment ($p = 0.05$).

Table 3. Total salt and mean soil organic matter (SOM) in the top 30 cm soil layer at the end of the fallow period, i.e., early June of 2017 and 2018 before maize sowing, for the TT, TT + SM, and NT + SM treatments. TT: traditional tillage for maize cultivation without straw return after maize harvest; TT + SM: traditional tillage with 100% straw mulching after harvest; NT + SM: no-till cultivation combined with 100% straw mulching. Means in the same year followed by a different letter are significantly different (p = 0.05).

Treatment Identifiers		Total Salt (g/m^2)	SOM (g/kg)
Year	**Treatments**		
2017	TT	3551.9 a	16.04 a
	TT + SM	3149.5 b	17.08 a
	NT + SM	3236.2 b	16.61 a
2018	TT	3424.0 a	16.65 b
	TT + SM	2553.7 c	19.61 a
	NT + SM	2969.6 b	17.29 b

3.3. SOM

Table 3 describes the pre-planting mean SOM in the top 30 cm soil layer at the end of the fallow period. Generally, the mean SOM tended to be highest under the TT + SM treatment, while TT had the lowest values, i.e., TT + SM > NT + SM > TT. Before the first cropping season of early June 2017, the three treatments had no significant difference in SOM. However, in 2018, TT + SM accelerated SOM significantly by 17.8% and 13.4%, in comparison to the TT and NT + SM treatments, respectively (p = 0.05).

3.4. Soil Bulk Density

Mean soil bulk density in the top 30 cm profile of the soil is shown in Figure 3; the means were measured prior to maize sowing. Generally, prior to the first cropping season (early June 2017), no significant difference in soil bulk density was observed between the TT, TT + SM, and NT + SM treatments. However, a significant improvement was observed in 2018 under the TT + SM treatment, which decreased the soil bulk density by 3.4% and by 2.7%, respectively (p = 0.05), in comparison to the TT and NT + SM treatments. In addition, the difference in 2018 between TT and NT + SM was not significant.

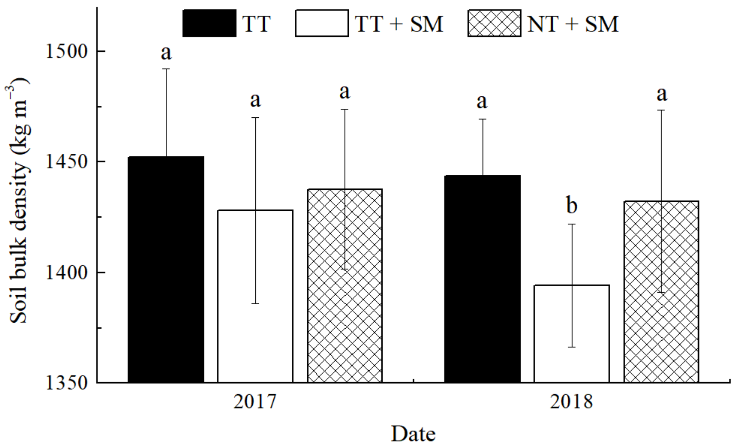

Figure 3. Mean soil bulk density to the depth of 30 cm for traditional tillage without straw return (TT), traditional tillage with straw mulching (TT + SM), and no-till cultivation combined with straw mulching (NT + SM) treatments. Data were measured before maize sowing. Mean values within the same year followed by a different letter are significantly different (p = 0.05).

3.5. SWC

Figure 4 shows the mean volumetric SWC in the upper 30 cm soil profile after each fallow period. Volumetric SWC under treatments with straw mulching tended to be higher throughout the 2-year experiments. Particularly, prior to the second cropping season in 2018, TT + SM significantly accumulated more volumetric SWC by 10.3% ($p = 0.05$), in comparison to the TT treatment. Furthermore, the mean values in volumetric SWC under the NT + SM treatment tended to be medium, but no significant variation was observed, both compared with the TT and TT + SM treatments.

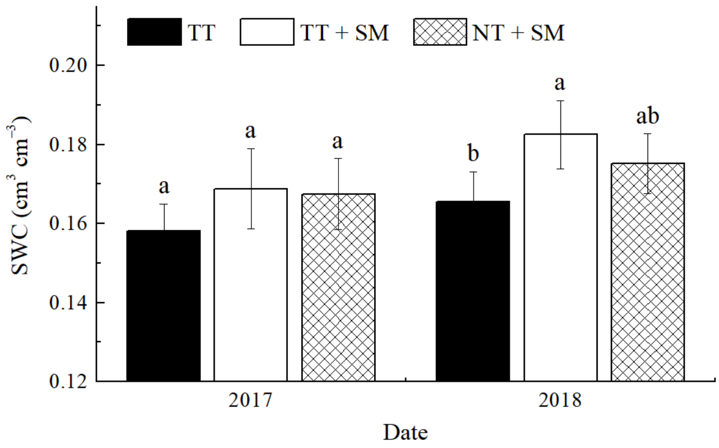

Figure 4. Mean volumetric soil water content (SWC) in the top 30 cm profile at the end of each fallow period, for the TT, TT + SM, and NT + SM treatments. TT: traditional tillage for maize cultivation without straw return after maize harvest; TT + SM: traditional tillage with 100% straw mulching after harvest; NT + SM: no-till cultivation combined with 100% straw mulching. Means in the same year followed by a different letter are significantly different ($p = 0.05$).

3.6. Crop Performance

At the end of the fallow period in early June, in-season maize cultivation was conducted, and the crop growth at maturity stage is listed in Table 4. No significant difference was observed regarding plant height among various treatments. Moreover, for root dry weight, means under treatments with straw mulching tended to be higher. In detail, TT + SM increased root dry weight by 16.2–18.7%, as compared with the TT treatment ($p = 0.05$). Moreover, compared with the TT treatment, no significant promotion was observed in root dry weight under the NT + SM treatment.

Table 4. Plant height and root dry weight at maturity stage, as well as the final grain yield for maize cultivation under the traditional tillage without straw return (TT), traditional tillage with straw mulching (TT + SM), and no-till cultivation combined with straw mulching (NT + SM) treatments. Mean values within a column in the same year followed by a different letter are significantly different ($p = 0.05$).

Treatment Identifiers		Plant Height (cm)	Root Dry Weight (g/plant)	Grain Yield (kg/hm^2)
Year	Treatments			
2017	TT	164.8 a	43.9 b	4655.3 b
	TT + SM	173.7 a	52.1 a	5009.7 a
	NT + SM	170.3 a	46.2 b	4741.3 b
2018	TT	172.5 a	47.2 b	4789.3 b
	TT + SM	181.2 a	54.8 a	5331.0 a
	NT + SM	179.3 a	51.4 a b	4914.7 b

Grain yield for each crop season followed a similar trend with that of root dry weight (Table 4). Treatments with straw mulching tended to harvest more grain, while the yield in TT was lower, i.e., TT + SM > NT + SM > TT. In detail, TT + SM increased grain yield by 7.6% in 2017 and 11.3% in 2018, when compared with the TT treatment (p = 0.05). Moreover, compared with the TT treatment, no significant promotion was observed for grain yield under the NT + SM treatment.

4. Discussion

It was reported that, under the one-crop-per-annum system of coastal regions, rather than the rhizosphere nutritional conditions within the cropping season, farmers must pay attention to salt fluctuations during fallow [28]. Due to monsoon and tidal activities, the farmland environment in coastal areas is difficult to predict and utilize. Particularly in the domestic Tianjin Binhai district of the west Bohai Gulf (the experimental plot in this paper), local farmers prefer to conduct maize cultivation resorting to the rainfall leaching in summer. However, salt accumulation in the topsoil during the fallow periods is less reported. Therefore, this study was extremely different from previous demonstrations.

Firstly, in response to such a "fallow + summer maize" rotation cropping system, we attempted to optimize fallow management to provide an acceptable rhizosphere environment for subsequent sowing. Prior to the fallow, we covered soil surface with the maize residues, and at the end of the fallow, positive information was obtained. After 2 years of "fallow + summer maize" rotation cultivation, the TT + SM treatment reduced EC and total salt in the upper 30 cm soil profile by 22.9% and 25.4% (p = 0.05) compared with TT. The results confirmed that fallow mulching was conducive to minimize the upward salt accumulation, which was consistent with Deng et al. [29] within an adjacent experimental region. This may be attributed to the following three reasons: first, the solar radiation on the surface is shielded by maize straw, thereby reducing the temperature of the topsoil; second, the exposed area was reduced; third, straw mulching is also conducive to the prevention of wind, which may result in the weakened soil evaporation and reduced the upward movement of water. Hence, we infer that fallow mulching is conducive to diminishing salt accumulation through inhibiting bottom salt rising to the topsoil via water evaporation, which was also reported by Yusefi et al. [30].

Secondly, we also focused on the physicochemical properties of the top 30 cm soil profile after fallow mulching. Beneficial results were observed in volumetric SWC, bulk density, and SOM before the second cropping season, as affected by mulching treatment. From farmland measurements, TT + SM appeared to increase volumetric SWC by 10.3%, accelerate SOM by 17.8%, and decrease bulk density by 3.4% (p = 0.05) in comparison to the TT treatment. Adequate soil water storage is a requisite for crop germination, growth, and thereby gaining higher grain yield in fresh-starved farming [31]. The results showed that pre-seeding volumetric SWC had a significantly positive correlation relationship with grain yield, with a correlation coefficient of 0.827 (p = 0.05, Figure 5). Similar to our findings, Choudhary and Kumar [32] reported that a higher soil moisture while sowing contributes to a better crop performance with mulching under maize-based cropping practice. Importantly, maize grain yield under different treatments was significantly related to the applied mulching practices (p = 0.05, Tables 4 and 5); the crop performance showed a trend of TT + SM > NT + SM > TT. The post-fallow SOM and grain yield with straw mulching were significantly accelerated than those without mulching (p = 0.05), which was consistent with Zhao et al. [33] and Xue et al. [34]. This could be explained by the alleviation of salt accumulation and the improvement of nutrients in the topsoil treated by fallow mulching.

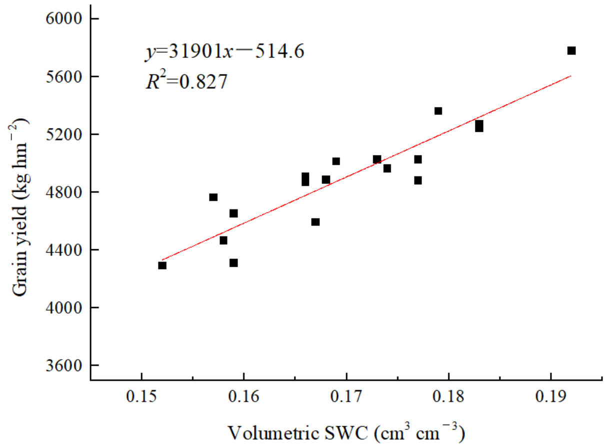

Figure 5. Relationship between pre-seeding volumetric soil water content (SWC) in the top 30 cm profile and in-season maize grain yield.

Table 5. ANOVA of the maize grain yield in line with the diverse treatments from 2016 to 2018. Y: year; T: treatments; Y × T: interaction influence of treatment and year. ** indicates significant difference at p = 0.01 level.

Variation Source	Degree of Freedom	Mean Square	*F*-Value	*p*-Value
T	2	329,061.5556	45.5246 **	0.0001
Y	1	197,610.3889	27.3388 **	0.0008
Y × T	2	14,636.2222	2.0249	0.1943
Error	8	7228.2222		
Total variation	17			

In terms of seedbed preparation (i.e., tillage mainly), we compared the effects of rotary tillage and no-till on crop growth in coastal salinized farmlands. The results showed that, under fallow mulching conditions, the rotary tillage seemed to be more favorable for matter accumulation (between the TT + SM and NT + SM treatments). This was due to better root development, which ultimately resulted in a higher maize yield [35], because rotary harrowing could loosen soil particles, cut off soil capillaries, and thereby slow down water evaporation, which is conducive to providing a better seedbed environment for sowing [36,37]. However, in coastal farmlands, soils are highly argillaceous with poor permeability, and in undisturbed soil, it is difficult to have positive impacts on root growing under the no-till treatment.

Meanwhile, this study was an adaptability exploration of conservation agriculture (CA) in coastal salt-affected soils. Despite the positive effects from the fallow mulching treatment, the no-till treatment did not achieve an optimal ecological environment and grain accumulation. In fact, we also conducted a no-till treatment alone (no-till seeding without fallow mulching), but only seldom was emergence monitored (results not shown). Pittelkow et al. [38] found that the no-till application alone had a negative impact on crop yield, while the negative effects of no-till could be minimized when other principles of CA (i.e., mulching or crop rotation) were applied. In dry or hydropenic climates, the yield profits with no-till combined with mulching may be due to improved soil moisture [39]. In this study, NT + SM gained an advantage in the post-fallow volumetric SWC by 5.8% and maize yield by 2.6% over the TT treatment after a 2-year cultivation, which was consistent with previous ones.

In the one-crop-per-annum cropping system, grain yield is only one of the diverse components that reflect soil productivity, and there is an urgent need for farmers and researchers to ameliorate farming management, among other socio-economic and ecological indicators. Especially in "fallow + summer maize" rotation systems, we are required to focus on both of seasonal cultivation and fallow management, rather than crop cultivation alone. The findings confirm our hypothesis that rational fallow management can reach a lower salt stress and higher water conditions for subsequent maize sowing. This will help to increase post-fallow crop yields.

However, there are several deficiencies in this research. Firstly, despite the improved soil physicochemical properties before sowing, soil evaporation during fallow was not monitored. In fact, the upward salt accumulation via capillaries is closely related to soil evaporation. Secondly, the principles of CA (i.e., no-till, soil cover, and crop rotation) were discussed in this study, but their positive influence under the no-till treatment was limited in response. A deeper interpretation of the farming patterns in coastal areas is required.

5. Conclusions

Compared with traditional tillage, fallow mulching showed an advantage in reducing the total salt of topsoil, increasing water storage, and enhancing maize growth. After 2 years of the "fallow + maize" rotation system cultivation, TT + SM reduced soil EC and the total salt of the upper 30 cm soil profile by 22.9% and 25.4% (p = 0.05), respectively, compared with the TT treatment. The results also indicate an improvement in volumetric SWC by 10.3%, SOM by 17.8%, and ultimately, grain yield by 11.3% (p = 0.05) under the TT + SM treatment.

Based on the above findings, this study could provide some guidance for scholars. Firstly, as a by-product from croplands after harvest, residues provide a method (retention by mulching) for solving agriculture-related social and economic problems, such as straw burning and biomass recycling. Secondly, aiming at coastal salinized soils, fallow mulching combined with crop rotation can also be extended to inland dry agricultural areas that require fallow to preserve soil moisture. Of course, agricultural production is a complicated, multifaceted collaborative system, and fallow cover is not an immediate management. In the coastal farming practice, it is recommended to carry out long-term fallow mulching to maintain an acceptable water and salt environment in the rhizosphere. Future studies will focus on the long-term impact of fallow mulching on rotation farming and multifaceted analyses in terms of transpiration, microorganism, soil structure, etc., will be introduced. In the meantime, this study will be applied in other soil environments, such as dryland or fresh-starved farming systems.

Author Contributions: Conceptualization, Y.Z.; methodology, L.H.; software, W.Y. and L.H.; formal analysis, Y.Z.; investigation, Y.Z.; data curation, L.H.; writing—original draft preparation, W.Y.; writing—review and editing, Y.Z.; funding acquisition, Y.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Natural Science Foundation of the Jiangsu Higher Education Institutions (20KJB416008), the Jiangsu Modern Agricultural Machinery Equipment and Technology Demonstration and Promotion Project (NJ2021-16), the Yangzhou University Interdisciplinary Research Foundation for Crop Science Discipline of Targeted Support (yzuxk202007).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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