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Buried Straw Layer Coupling Film Mulching Regulates Soil Salinity of Coastal Tidal Soil and Improves Maize (*Zea mays* L.) Growth

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Abstract: [Aims] The saline soil in continuous silting tidal areas will become a crucial reserved land resource in China. A prominent problem is controlling soil salinization for improving agricultural water and land resources' productivity in coastal areas. [Methods] An experiment was conducted to study the effects of different mulching and tillage measures on soil salt-water status and maize growth. There were four treatments: (1) film mulching (FM), by only setting a transparent plastic film (with a thickness of 6 μm) on the surface soil; (2) straw deep-burying (SDB), in which only straw was buried as a layer at a soil depth of 30 cm; (3) combining film mulch with deep-buried straw (F+S), in which a straw layer was buried at a soil depth of 30 cm with plastic film mulching on the soil surface; and (4) control (CK), by simulating standard local practice. [Results] The results showed that the soil water storage (*SWS*) under FM and F+S was significantly higher than others, and F+S showed the best role in soil water conservation. The film mulching had a reasonable effect on soil salinity regulation during the whole maize growth stage; the soil salt content at 0–30 cm was decreased by 1 g/kg and 0.74 g/kg under F+S and FM, respectively. Compared to CK, the plant height, *LAI*, SPAD value, and yield were all improved under mulching and tillage. The growth process of maize and water-use efficiency (*WUE*) under F+S was more significantly improved than those under other treatments. [Conclusions] Overall, the F+S can be recommended as a suitable strategy for regulating soil salt and moisture, and thus improving crop productivity in coastal tidal areas.

Keywords: soil moisture; soil salt accumulation; salt leaching; crop growth and development; water use efficiency

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1. Introduction

According to the data of the Third National Land Survey, by the end of 2019, the cultivated land in China had decreased by 7.33 million ha compared with 135.33 million ha at the end of 2009, with an average annual decrease of more than 0.67 million ha, and the cultivated land area was approaching the red line of farmland protection of 120 million ha [1,2]. The Saline-alkali land is widely distributed in China, ranging from coastal areas to inland regions, and from humid areas to extremely arid desert [3]. According to statistics, the saline-alkali land area in China accounts for 6.62% of the total arable land area [4]. The Northern Jiangsu Plain along the shore of the Yellow Sea, in which 70% of the area is siltation flat, and the coastal tidal flat area is up to 0.76 million ha, accounts for about 7.06% of the total arable land area in Jiangsu Province [5]. The saline soil in the continuous silting tidal area will become an important and valuable land resource with appropriate utilization. However, the soil in the tidal flat area is mainly alluvial saline soil, which is a typical silty coastal saline soil with high soil salt content, low ability of water storage, and poor fertilizer condition [5]. Therefore, understanding how to reduce the soil salt content in the root depth layer, enhance water retention ability and restrain salt movement to root depth, and ensure a suitable moisture situation and safe soil salt content level in the root depth, has become the key problem in controlling soil salinization and improving the productivity of agricultural water and land resources.

At present, salinization is mainly relieved by leaching, combining irrigation and drainage technology, which consumes a large amount of water resources. Rational mulch tillage measures are needed to restrain soil salt movement and improve the environment for crop emergence and growth. Many researchers reported that plastic film mulching can improve the soil moisture and heat condition of the surface layer, significantly improve topsoil moisture, inhibit salt accumulation in surface soil, and improve water-use efficiency [6–8]. Zhang et al. [9] also studied the effect of subsoil plastic film mulch on the growth of winter wheat, and reported that subsoil plastic film mulch can effectively improve winter wheat yield and water-use efficiency in rain-fed areas. Xie et al. [10] found that mulching cultivation could effectively regulate and stabilize temperature, improve soil water and heat status, and enhance the soil's ability to retain fertilizer and water, thus effectively increasing corn yield.

Straw deep-burying, a type of straw return approach, has already been widely used to reduce soil evaporation and benefit agriculture. In addition, straw buried in the soil can enrich soil organic matter and nutrient elements such as nitrogen, phosphorus, and potassium [11,12], which is important for coastal tidal soil by enhancing soil quality and increasing agricultural productivity. Wang et al. [13] also revealed that a buried straw layer changed the original soil physical structure, reduced the soil bulk density, enriched the soil pore structure, and enhanced the soil ventilation permeability. Dong et al. [14] reported that straw depth could reduce the tillable layer bulk density and soil tightness of black soil, and improve soil water-holding capacity, among which the high amount of chopped straw returned to the field had the best improvement on soil physical properties through three years of field experiment on straw buried and returned to the field. Liu [15] found that a buried straw layer can inhibit the rapid leakage of surface soil water, enhance the water retention ability of the tilled layer, promote the downward leaching of salt, reduce the soil salt in the tilled layer, and thus increase the yield of sunflowers.

It can be found from above that the effects of single film mulch or the straw deep-burying approach have been widely reported as they played a beneficial role in soil water and salt regulation [16,17]. However, what about the performance of combining film mulch with deep-buried straw? Does this still work for the saline soil in coastal tidal areas? We hypothesize that the film mulch can supply a better environment for buried straw layer development, so as to show better water retention and salt regulation effects, as well as enhance soil fertility. Based on this, it has become a meaningful topic that if the soil moisture and salt environment, the fertility level of the salinized soil in the tidal area will be improved, as well as the crop yield eventually being enhanced when the combination of plastic film mulching and straw deep-burial were applied in the management of salinized soil land. Thus, we conducted a pot experiment (1) to study the effects of the film mulch and straw deep-burying as well as their coupling management on soil salt-water status, (2) to discuss the maize growth and yield under mulching and tillage, and examine the applicability of film mulching and straw deep-burying to improve the productivity of coastal tidal soil.

2. Materials and Methods

2.1. Tested Soil and Materials

The soil used for the pot trial was collected from coastal areas located in Dongtai city, Jiangsu Province. The soil mechanical composition was tested by an MS-2000 laser particle size analyzer, and it can be classified as silty sandy loam (International system); the detailed soil properties are listed in Table 1.

Table 1. The properties of tested soil.

Soil Bulk Density	Field Capacity	Soil Organic Matter	Available Nitrogen	Water Soluble Organic Carbon	pH	Soil Particle Composition (%)		
(g/cm^3)	(%)	(g/kg)	(mg/kg)	(mg/kg)		Clay (0–0.002 mm)	Silt (0.002–0.02 mm)	Sand (0.02–2 mm)
1.4	24.55	8.14 ± 0.07	15.66 ± 4.30	<0.5	7.96 ± 0.01	2.9	46.41	50.69

The salt in the tested soil is mainly composed of sodium chloride, with a soil salinity of (5.43 ± 0.08) g/kg, and soil solution electrical conductivity of (2024 ± 23) µS/cm belonging to chloride saline soil; the detailed ion concentrations are listed in Table 2.

Table 2. The soil salinity and ion concentration.

Total Salt Content	EC	Ion Concentration (mg/kg)					
(g/kg)	(mS/cm)	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$K^+ + Na^+$
5.43 ± 0.08	2.02 ± 0.02	284.8 ± 14.4	2587.9 ± 28.9	576.4 ± 39.2	126.9 ± 9.5	72.9 ± 17.2	1778.7 ± 44.4

Notes: the value after the "±" is the standard deviation of replicates for samples.

Prior to the experiment, the collected soil was air-dried and sieved via a 2 mm stainless steel sieve. The soil was fertilized at a rate equivalent to 65.7 g/m^2 with a compound fertilizer as the base fertilizer, of which the percentage of N-P-K was 15:15:15, and the total nutrient content was ≥45%. Following fertilizer amendment, a small amount of deionized water was finely mixed and equilibrated for 48 h, and the initial soil moisture was maintained at (8.32 ± 1.51)%. The soil was thoroughly mixed to minimize variability and packed into PVC pots (diameter 42 cm × height 52 cm) with layers every 5 cm to achieve a natural bulk density of around 1.4 g/cm^3. The total soil depth of the pot was 47 cm with a 5 cm gap to retain water. Each layer was lightly raked before packing the next layer to minimize discontinuities between layers. Apertures were drilled on the bottom of the pot to allow drainage. In order to prevent the upper fine particle from plugging the apertures, 2 layers of geotextile were set at the bottom before packing the soil.

Maize cultivar of Zhengdan-958 grown widely in China was used, 3 seeds were sown in each pot on 15 April 2019, then the seedlings were thinned to leave only one uniform seedling in each pot after germination. In order to guarantee normal growth, the maize was fertilized in the jointing stage and booting stage at the rate of 400 kg/ha with the same base fertilizer. The other agronomic management was the same among all the treatments during the growing stage.

2.2. Experimental Site and Design

The experiment was carried out in a greenhouse at the South Road Campus of Yangzhou University (119°25′17″ E, 32°22′33″ N) in southern China from April to July in 2019. The site is classified as a humid subtropical climate (Köppen Climate), which is a typical climate of eastern China. The greenhouse was completely exposed to the outside environment with side windows open, and only prevents the pot from receiving natural rainfall.

The study evaluated 4 treatments with 3 replicates, one being the pot only with packed soil was used as a control to simulate the standard local practice, neither mulch the film nor bury the straw layer (CK). The other 3 treatments were: (1) Film mulching (FM), by only setting transparent plastic film (with a thickness of 6µm) on the surface of the soil in the pot; (2) deep-buried straw layer (SDB), by only burying straw as a layer at the soil depth of 30 cm. The straw layer was formed of wheat straw which was chopped into pieces at the length of 3–5 cm, and then packed to around 3 cm in depth; (3) combining film mulch with deep-buried straw (F+S), by burying a straw layer at the soil depth of 30 cm and placing mulch plastic film on the soil surface, that means combining treatments SDB and FM.

The average precipitation during year 1981–2010 in Dongtai was 1061.1 mm, the precipitation of June to August accounts for 50%. The average water requirement of spring Maize in the Huang-Huai-Hai region was 456.7 mm. To comprehensively consider the local precipitation and water requirement of Maize, the irrigation schedule for the pot experiment is listed in Table 3. In order to leach the salt and ensure the plant germination of maize, each pot was irrigated at 108.3 mm on 10 April.

Table 3. The irrigation schedule for pots.

Irrigation Date	10th April	15th May	6th June	21st June	5th July
Irrigating water quota (mm)	108.3	80.2	66.4	66.4	66.9

2.3. Observation and Measurement

The leacheate after irrigation was collected and measured for volume and salt content. Soil samples were taken at each 10 cm depth by soil auger during growth stage, and the last layer was 40–47 cm. The soil was divided into 2 parts, in one, the soil water content was measured using the oven-drying method, and the other part was air-dried, ground, and passed through a 2 mm sieve.

The soil water content was calculated as the following:

$$\omega = (W - D)/D \times 100\% \tag{1}$$

where the ω is the soil water content (%), W is the fresh weight of each soil sample (g), and D is the dry weight (g) (the weight after drying at 105 °C over 8 h to a constant weight).

The soil EC were determined in a soil solution that extracts soil with distilled water (soil to water ratio, 1:5) using a conductivity instrument (DDSJ-308A, Shanghai INESA Scientific Instrument Co., Ltd., Shanghai, China). According to Li et al. [18], the salt content and EC in coastal saline soil can be translated as the following:

$$S = 3.2EC_{1:5} - 0.0679 \tag{2}$$

where S was the soil salt content (g/kg), and $EC_{1:5}$was the EC value of the soil-extracted solution (mS/cm). The leaching solution after irrigation was collected and measured for volume and salt content.

The soil water storage in the pot was calculated by 10 cm as the following:

$$W = h \times \omega \times \rho \times 10 \tag{3}$$

where W is the soil water storage (mm), h is the soil depth of the calculated soil layer (cm), and ρ is the volume weight of soil (g/cm^3).

During the growth stage, the plant height was measured by a steel tap (the accuracy is 0.01 m) from the ground to the highest point of natural extension of all leaves. The leaf area index (LAI) was calculated as the following, by measuring the length and width of one leaf,

$$LAI = K\frac{\sum_{i=1}^{n}(L_i \times B_i)}{A} \tag{4}$$

where K was the crop simulate coefficient, which is 0.75 for maize; Li and Bi was the length and width of the leaf (cm), respectively; and A was the land area occupied by the plant (cm^2). The Chlorophyll content was determined using a SPAD chlorophyll meter (SPAD-502), and the result was expressed as SPAD value, which was the relative content of chlorophyll in leaves.

At harvest, maize stems, leaves, and ears were collected and dried in an oven at 70 °C until the weight remained constant. Dry shoot (stem and leaves) biomass, number of rows, kernel number, 100-grain, and total grain yield weights were measured. The maize accumulated *ET* during the growth stage was estimated from the soil water balance in the pots. Maize water-use efficiency (*WUE*) was calculated as grain yield to total *ET* ratio.

2.4. Statistical Analysis

The data were calculated by Microsoft Excel 2010 (Microsoft Corporation), the significant differences amongst treatments were determined by ANOVA using SPSS 20.0 statistical program (SPSS, Chicago, IL, USA). The Origin 8.0 (Origin Lab) was used for figures plotting.

3. Results

3.1. The Soil Water Content Conditions

The soil water storage (SWS) indicates the soil water supply to crops during the growth stage (Figure 1), which was influenced by irrigation, field atmosphere, crop root uptake, and filed mulch tillage management.

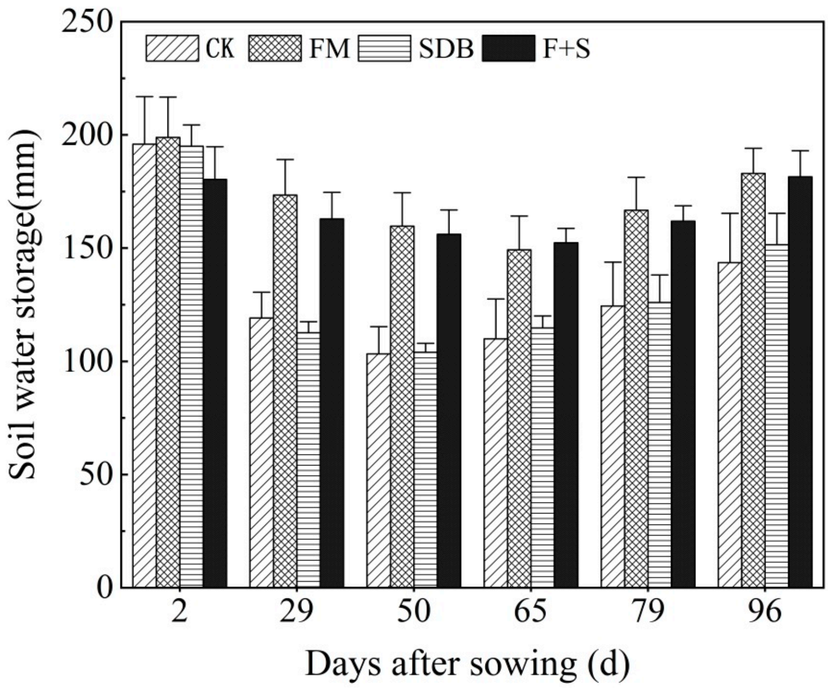

Figure 1. The soil water storage under each treatment with days after sowing.

With the days after sowing, the SWS initially declined to their lowest at day 50 to day 65, and then increased. The decline may not only be caused by the maize plant uptake, but may also be related to the high temperature and intensive evaporation. Expect the SWS after 2 days, the following results can be divided to two groups: the SWSs derived under treatments with surface film mulching, and the ones under treatments without mulching. The former ones were significantly higher than the latter ones, especially during the later growth stage of maize, the inhibition of film on soil moisture evaporation was increasingly obvious with the air temperature raise. Except for the SWS after 65 days, the SWS under FM was slightly higher than that under F+S, while there was no significant difference in SWS between FM and F+S. Refer to the SWS under SDB and CK, it was slightly higher under CK during the early growth stage, and reversed at 50 days after sowing, which might be the hindering effects of the buried straw layer for irrigation water infiltration, which reduced the leakage and played a role in water retention. The reason for the early low SWS under SDB could be attributed to a high decomposing intensity of the straw organic matter buried in the soil, as it will absorb and consume a large amount of soil moisture in the early decomposing process.

3.2. The Soil Salinity Dynamics

Soil salinity is a serious threat to crop productivity. The soil salt dynamics in root depth (0–30 cm) during each growth stage is shown in Figure 2; above the 0 line represents salt accumulation, reversely, below the 0 line represents salt leaching. The salt accumulation and leaching mainly occurred at the seeding stage to jointing stage, and with a slight change in the following growth stage. The soil salt under SDB leached around 0.2 g/kg, and then continuously accumulated until harvest; conversely, the salt under FM was continuously leached except in the seeding stage. The soil salt accumulated throughout the growth stage with a decreasing rate except in booting stage.

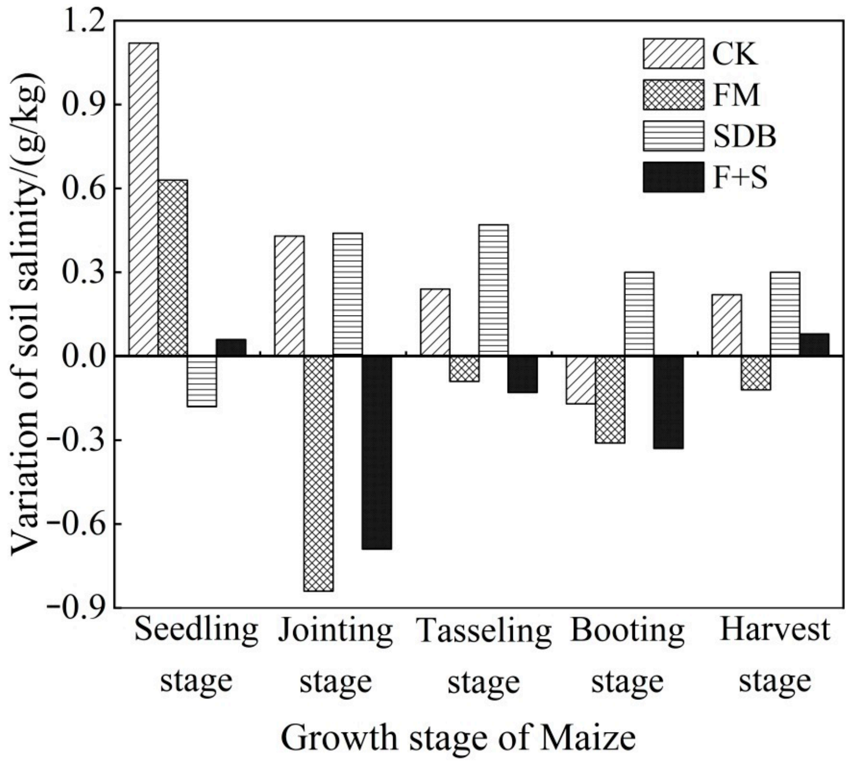

Figure 2. The soil salinity dynamics in root depth during each growth stage.

In order to clarify the comprehensive soil salt regulation under each treatment, the salt accumulation rate in root depth (0–30 cm) was calculated in Table 4. As the straw layer was buried under SDB and F+S, the initial soil salinity before sowing was higher than in the other treatments. Compared to the beginning of the growth stage, the soil salinity at 0–30 cm was decreased by 1 g/kg and 0.74 g/kg under F+S and FM, respectively. Whereas, under CK and SDB, the salt accumulating rate was even up to 136.3% under CK, which indicates a serious salt accumulation in crop root depth. The salt under SDB was eventually accumulated in root depth over the growth stage, but its salt accumulation rate was much lower than that under CK, indicating a salt control of the buried straw layer to some extent.

Table 4. The soil salinity dynamics under each treatment.

Treatment	Salinity before Sowing (g/kg)	Salinity at Harvest (g/kg)	Salt Accumulation (g/kg)	Salt Accumulating Rate (%)
CK	1.35 ± 0.81	3.19 ± 0.16	1.84	136.3%
FM	1.35 ± 0.81	0.61 ± 0.10	−0.74	−54.8%
SDB	1.68 ± 1.58	3.02 ± 0.12	1.34	79.8%
F+S	1.68 ± 1.58	0.68 ± 0.06	−1	−59.5%

Notes: the value after the "±" is the standard deviation of replicates for each treatment.

3.3. The Maize Growth and Yield

Salt and water stress are the main limits on crop growth in saline soil areas; water deficit and high salinity in surface soil will affect crop emergence, inhibit plant growth, and thus lead to crop yield decline. The different mulching and tillage measures can enhance soil moisture retention capacity and control the soil salinity in root depth, thereby improving the growth environment of crops.

3.3.1. The Growth Progress of Maize

It is reported that film mulch on the soil surface can alter the soil moisture and temperature, and thus affect the crop growth process; the periods of the growth stage under each treatment are listed in Table 5.

Table 5. The growth process of maize.

Treatments	Sowing Data (M/D)	Emergence		Tasseling		Physiological Maturity	
		Data (M/D)	Periods (d)	Data (M/D)	Periods (d)	Data (M/D)	Periods (d)
CK	4/17	4.22	5	6/23	63	7/21	91
FM	4/17	4/21	4	6/15	55	7/16	86
SDB	4/17	4/22	5	6/22	62	7/19	89
F+S	4/17	4/21	4	6/14	54	7/14	84

It can be seen from Table 5 that, under the same sowing date, irrigation, and fertility management, the maize under FM and F+S germinated 1 day earlier than the other treatments. The total growth periods until physiological maturity were recorded as 84, 86, 89, and 91 days for F+S, FM, SDB, and CK, respectively.

3.3.2. The above-Ground Biomass of Maize

Biomass represents the accumulation of organic matter during crop growth, and is an important indicator to evaluate the crop growth status. The above-ground biomass of maize at the seedling and harvest stages is shown in Figure 3. It can be seen that the above-ground biomass during the early seedling stage (18 days) was similar and showed no significant difference among the treatments. Whereas, at the harvest stage (91 days), the above-ground biomass under F+S, FM, and SDB were significantly higher than that under CK, about 1.74, 1.46, and 1.36 times of that under CK, respectively. The F+S produced most above-ground biomass among all treatments at harvest, but there is no significant difference with FM and SDB.

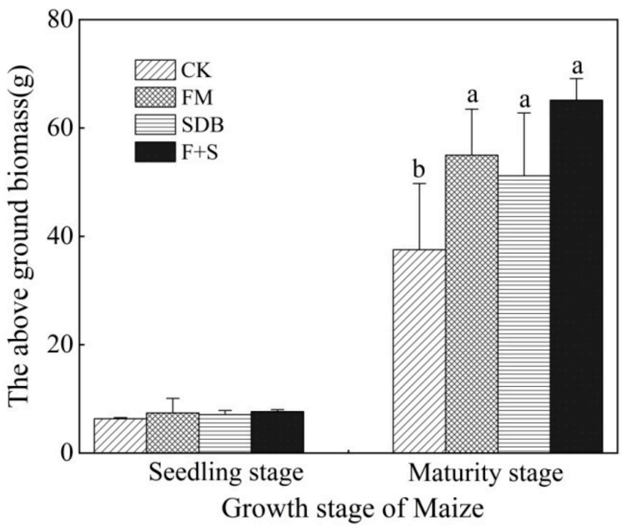

Figure 3. The above-ground biomass of maize at seedling stage and maturity stages. Notes: The "a" and "b" indicates that there is a significant difference between the treatments.

3.3.3. The Plant Height

The plant height was an important growth index of crops, which can reflect the longitudinal growth of plants. The variation in maize plant height under different treatments is shown in Figure 4. The plant height under each treatment roughly varied the same amount during the whole growth stage. It increased rapidly before the tasseling stage (59 days), then increased at a gradually declined rate after the tasseling stage. It reached the maximum value at the booting stage (74 days), and then decreased slightly until harvest. The maximum maize plant height was 22.3%, 22.0%, and 14.8% higher under FM, F+S, and SDB than that under CK, respectively. The plant height under F+S was the highest during the whole growth stage. There was almost no difference in plant height among treatments before the jointing stage (35 days). After that, the plant height under FM and F+S was rapidly increased, and significantly higher than that under CK and SDB.

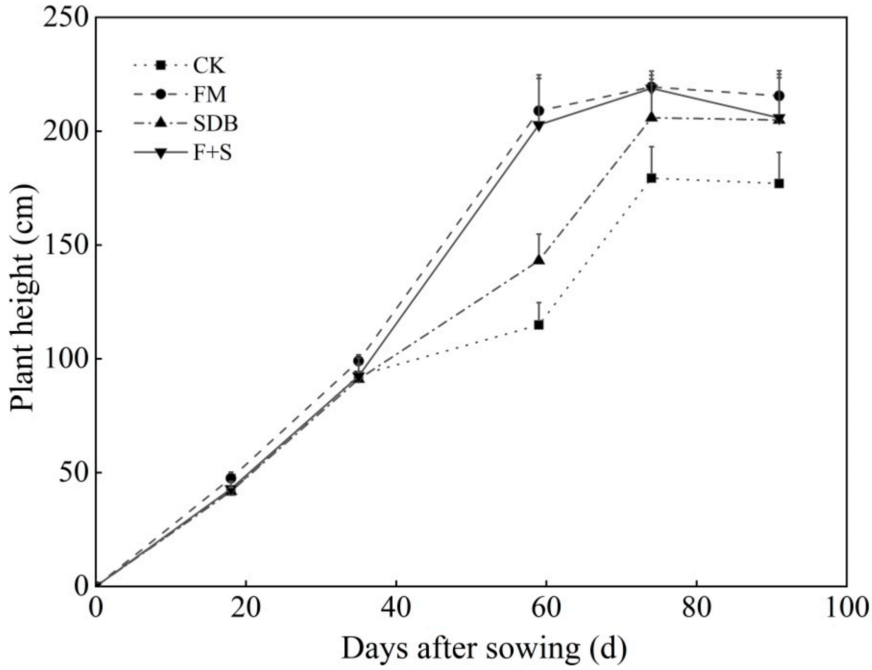

Figure 4. The plant height variation during maize growth stage under different treatments.

3.3.4. The Chlorophyll Content

A higher chlorophyll content in leaves indicates a better growth of crops. Former studies showed that chlorophyll content in leaves was positively correlated with SPAD value. Therefore, we measured the SPAD value of maize leaves during the growth stage and listed them in Table 6. Generally speaking, the SPAD value under each treatment showed a similar tendency with days after growing. It slightly decreased at the jointing stage (35 days), and increased to a peak at the tasseling (59 days) stage, the highest SPAD value reached 48.82 under F+S, then decreased again at the booting stage (74 days). There was no significant difference in SPAD values between the treatments during the seedling stage (18 days) and the jointing stage. The SPAD value under F+S was higher than that under others during the whole growth stage, but only reached a significant level at the tasseling stage and booting stage ($p < 0.05$), while the SPAD value under CK was significantly lower than that under others ($p < 0.05$) in the same period. This indicates either film mulching on the surface or that deeply burying the straw plays a role in crop growth, and the maize under compound treatment (F+S) grew better than others, even at the key growth stage.

Table 6. The *SPAD* value under different treatments.

Treatment	Seedling Stage	Jointing Stage	Tasseling Stage	Booting Stage
CK	37.54 ± 1.83 a	36.56 ± 1.55 a	40.42 ± 1.53 d	30.88 ± 3.82 c
FM	36.58 ± 3.00 a	35.70 ± 0.43 b	46.52 ± 1.05 b	37.22 ± 5.85 b
SDB	37.10 ± 2.12 a	36.96 ± 0.65 a	43.30 ± 0.98 c	37.68 ± 3.17 b
F+S	40.38 ± 4.57 a	37.30 ± 0.35 a	48.82 ± 0.49 a	45.40 ± 1.29 a

Notes: the value after the "±" is the standard deviation of replicates for each treatment, different lowercase letters after the same column indicate significant difference ($p < 0.05$).

3.3.5. The Leaf Area Index

The leaf area index (*LAI*) is also an important indicator of crop growth. We analyzed the leaf area indexes of maize at different growth stages in Table 7.

Table 7. The leaf area indexes under each treatments unit: (cm^2/cm^2).

Treatment	Seedling Stage	Jointing Stage	Tasseling Stage	Booting Stage
CK	0.071 ± 0.04 ab	0.488 ± 0.010 b	1.948 ± 0.677 b	1.126 ± 0.195 b
FM	0.066 ± 0.006 b	0.574 ± 0.174 ab	2.702 ± 0.595 a	1.321 ± 0.122 ab
SDB	0.075 ± 0.005 a	0.508 ± 0.023 b	2.470 ± 0.681 ab	1.466 ± 0.261 a
F+S	0.075 ± 0.002 a	0.681 ± 0.039 a	2.806 ± 0.293 a	1.594 ± 0.257 a

Notes: the value after the "±" is the standard deviation of replicates for each treatments, different lowercase letters after the same column indicate significant difference ($p < 0.05$).

The leaf area index increased from the seedling stage and peaked at the tasseling stage, the maximum *LAI* was 2.806 under F+S. After that, the leaves began to age and wither, and led to *LAI* decrease. The *LAI* under F+S was higher than that under others during the whole growth stage, while that under CK was lowest. At the jointing stage, the *LAI* under F+S was significantly higher than that under no mulching treatments (SDB and CK). At the tasseling stage and booting stage, the *LAI* showed no significant difference between treatments except CK. In the tasseling stage, the *LAI* under F+S, FM, and SDB increased by 44.0%, 38.7%, and 26.8% compared to CK, respectively.

3.3.6. The Maize Yield and WUE

Due to the high soil salinity and low fertility of the tested soil that was taken from a coastal area, the maize yield was far lower than the normal yield of the tested maize varieties, and only per plant yield was analyzed, as calculated in Table 8.

Table 8. The yield and its constituent factors analysis.

Treatments	Ear Length (cm)	Ear Diameter (cm)	Kernel Number per Spike	100-Grain Weight (g)	Yield per Plant (g)	*WUE* (kg/m^3)
CK	8.6 ± 1.3 b	2.84 ± 0.56 b	112 ± 31 b	9.533 ± 2.132 c	10.17 ± 2.34 b	0.312 ± 0.012 c
FM	9.8 ± 2.1 a	3.27 ± 0.77 a	240 ± 47 a	15.484 ± 1.542 b	24.78 ± 5.23 a	0.512 ± 0.114 b
SDB	9.4 ± 0.8 b	2.96 ± 0.82 b	153 ± 15 b	14.892 ± 0.372 b	15.21 ± 4.38 ab	0.383 ± 0.139 b
F+S	10.7 ± 1.6 a	3.48 ± 0.47 a	240 ± 22 a	19.409 ± 1.023 a	27.81 ± 4.42 a	0.680 ± 0.218 a

Compared to CK, weather film mulching or straw deep-burying increased the maize yield per plant, ear length, ear diameter, kernel number per spike, and 100-grain weight. The ear length, ear diameter, and kernel number per spike under F+S and FM were significantly higher than that under SDB and CK. Compared to CK, the 100-grain weight under F+S, FM, and SDB was significantly increased by 103.6%, 62.4%, and 56.2%, respectively. The treatments with film mulching (both FM and F+S) produced a higher maize yield; compared to CK, the yield under the F+S treatment significantly increased by 159.7% ($p < 0.05$). The water-use efficiency (*WUE*) under F+S was significantly higher than that under other treatments ($p < 0.05$); the *WUE* under FM was much higher than SDB, but did not reach a significant level; and the *WUE* under CK was lowest, almost half of that under F+S.

4. Discussion

The effects of film mulching on soil water conservation have been widely reported across the literature [19,20]. Considering the soil water storage (SWS) under each treatment, it was usually influenced by the atmospheric climatic condition, and dramatically dropped when the temperature was relatively high and the evaporation was intensive. In our study, the soil water conditions under both film mulching (F) and combining film mulch with deep-buried straw (F+S) were significantly favorable, which indicates that the film mulching is the main factor for increasing the SWS in this climate condition, in accordance with the results from Zhang et al. [21]. The influence of buried straw on soil water condition is mainly shown as water infiltration retention. In addition, a large amount of soil water will be needed for the early decomposition process of buried straw, so induced low SWS under the treatments with buried straw are even lower than that under CK during the early growth of maize, but the SWS recovered to be higher than that under CK at the later growth stage. It is worth noting that the SWS under F+S at 2 days after sowing was much lower than that under others, which might be caused by the decomposing of straw. Moreover, the soil temperature was more comfortable during the film mulching, which then stimulated the decomposing process and induced much more water consumption. Considering the large water consumption by buried straw at the early stage (usually the seedling stage), severe water competition would occur between the buried straw and plant, even in areas with spring drought. Therefore, in further studies, carrying out straw burying ahead of seed sowing should be considered, thus ensuring adequate soil moisture for seed germination. Moreover, as the low initial soil moisture was induced by buried straw, much more water will be infiltrated once rainfall occurs, thereby improving the rainfall utilization efficiency to some extent.

The film mulch and deep-straw burying can also relieve soil salinity; Zhang et al. [22] concluded that the soil moisture of surface soil was enhanced, and the soil salinity was much lower with film mulch, so film mulching can effectively inhibit soil salinization. Lu et al. [23] found that the buried straw layer enhanced salt leaching in the root depth, and the soil salt was decreased by 18.9%. Similarly, in our study, the soil salinity at 0–30 cm depth at the end of the growth stage under the treatments with film mulching was reduced to half of that at the beginning, and the desalinization rate under F+S was up to 54.08%, especially higher than that under single mulching, which revealed that F+S can effectively block the soil salt to stay below the root depth, thus providing a suitable soil environment for maize growth. It is worth noting that F+S and FM played a satisfactory role during the whole maize growth stage, while SDB only effectively inhibited soil salt during the seeding stage, which was in accordance with the research of Zhao et al. [24]. This might be explained by the buried straw layer being able to block the continuity of soil capillary and delay water infiltration, and then prolong the residence time of infiltration water in the soil above the straw layer, thus effectively enhancing the leaching effect of soil salt [25]. In addition, the buried straw layer also prevents the salt moving upward from the deep soil during evaporation, and the salt accumulation rate under SDB is still lower than that under CK, which indicates a good salt suppression of the buried straw layer. This is in accordance with Liu [15], in terms of the buried straw layer controlling salt accumulation in the root zone. In general, both film mulching and the deep-buried straw layer contribute to salt suppression, and the F+S performed best.

It was demonstrated by Zhang et al. [21] that film mulching enhanced the maize biomass and dry matter accumulation level, and clearly increased maize grain yield. It is also concluded that the combined application of straw mulch and buried straw layers had significant effects on sunflower growth, and obtained the highest sunflower shoot biomass over a 3-year experiment in the Hetao Irrigation Distract, Inner Mongolia, China [26]. Similarly, in our study, a higher soil water storage and lower soil salinity stimulated maize growth and yield, as indicated by the early emergence, higher above-ground biomass, more satisfied yield and *WUE* with taller plants, higher SPAD value, higher leaf area index under film mulching, and straw deep-burying treatments than CK. The F+S treatment was better than single film mulching (FM) or the straw deep-burying treatment (SDB) in improving maize growth, due to the continuous warming and moisture conservation effect on the soil environment. The result under SDB was not as good as film mulched treatments, and just slightly better than CK, especially in the early growth stage, while in the later stage, the SPAD value and *LAI* was stimulated, even higher than that under FM in booting stage, which may be related to improved nutrient status as straw composition. The maize yield per plant under film mulched treatments was significantly higher than that under non-film mulching treatments, and the highest yield was obtained under F+S. The 100-grain weight under SDB was significantly higher than that under CK, which was in accordance with the research of Wang et al. [13]. Li et al. [27] revealed the effects of combined ditch buried straw return in a ridge–furrow plastic film mulch (RP) system on crop yield and soil organic matter dynamics, and concluded that it was a sustainable practice in dryland farming, as it can increase soil organic carbon concentrations, total nitrogen in surface soil, and maize yield compared with flat cultivation and RP without buried straw. In our study, the combined measure also showed an outstanding advantage in improving the soil water, fertilizer, atmosphere, and heat conditions, thus ensuring crop productivity.

5. Conclusions

Combining film mulch with deep-buried straw (F+S) showed the best role in soil water conservation, film mulching is the main factor influencing soil water storage, and the SWS under treatments with film mulching (FM and F+S) was significantly higher than others. The SWS under SDB was low in the early growth stage, then recovered to an obvious higher level than that under CK in the later growth stage.

The film mulching had a reasonable effect on soil salinity regulation during the whole maize growth stage, and the best effect was obtained under F+S. There is an overall salt accumulation under single SDB treatment, but it is much lower than that under CK, and the salt regulation effects of SDB are mainly shown in the early growth stage.

The film mulching treatments condensed the time for emergence, and the growth process of maize was obviously advanced under F+S. According to the above-ground biomass, plant height, *LAI*, and SPAD value, the yield per plant were all improved under each treatment. The F+S can improve the soil water and salt environment, promote crop growth, and relieve water and salt stress on crop growth. It can be recommended as a suitable strategy for regulating soil salt and water, improving crop productivity, and ensuring food security in coastal tidal areas.

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