Effects of Brackish Water Drip Irrigation Under Plastic Mulch on Cotton Growth and Yield: Postprint

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Abstract

Southern Xinjiang suffers from freshwater scarcity, while shallow saline groundwater and irrigation drainage resources are relatively abundant. Investigating the effects of freshwater-saline water mixed irrigation on cotton growth and yield to develop a simple application model holds significant importance for mitigating drought losses in cotton-growing regions of southern Xinjiang during extreme drought years. Using irrigation surface water (salinity 0.38–0.75 $g \cdot L^{-1}$) as the control and drainage ditch saline water (salinity 9.81-11.81 $g \cdot L^{-1}$) mixed at different ratios, six gradient irrigation water treatments were established: freshwater:saline ratio 1:0 (control); 4:1 (Treatment 1); 3:2 (Treatment 2); 2:3 (Treatment 3); 1:4 (Treatment 4); and 0:1 (Treatment 5), for a field irrigation experiment on cotton. Results showed: (1) With increasing irrigation water salinity, cotton physiological traits exhibited a declining trend. Compared with the control, Treatment 1 irrigation water had minimal impact on cotton growth, with cotton yield decreasing by 11.85% relative to the control. (2) Irrigation water productivity decreased with increasing irrigation water salinity, with Treatment 1 showing the smallest reduction compared with the control. (3) Soil salinity in the 10–40 cm layer exhibited accumulation under different brackish water treatments, with the control showing a 14.08% increase in soil salinity after the final irrigation compared with before the first irrigation, and Treatment 5 showing the maximum increase of 173.08%. The irrigation water ratio of 4:1, i.e., salinity of 2.36–3.39 $g \cdot L^{-1}$, had minimal impact on cotton growth, yield, irrigation water productivity, and soil salinity. This demonstrates that adopting appropriate fresh-saline water mixed irrigation methods during drought and water shortage periods plays an important role in alleviating regional water resource scarcity and ensuring cotton yield.

Full Text

Effect of Drip Irrigation Under Brackish Water Film on Cotton Growth and Yield

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Abstract

Southern Xinjiang suffers from freshwater scarcity while possessing relatively abundant shallow saline groundwater and irrigation drainage resources. Investigating the effects of mixed brackish water irrigation on cotton growth and yield is essential for developing practical application models to mitigate drought losses in cotton-growing regions during extreme drought years. This study employed surface irrigation water (mineralization degree 0.38–0.75 $g \cdot L^{-1}$) as a control and mixed drainage channel saline water (mineralization degree 9.81–11.81 $g \cdot L^{-1}$) in varying proportions to create six salinity gradient treatments for a field cotton irrigation experiment: 1:0 freshwater/saline ratio (control); 4:1 freshwater/saline ratio (Treatment 1); 3:2 freshwater/saline ratio (Treatment 2); 2:3 freshwater/saline ratio (Treatment 3); 1:4 freshwater/saline ratio (Treatment 4); and 0:1 freshwater/saline ratio (Treatment 5). The results demonstrated that cotton physiological characteristics declined as irrigation water salinity increased. Compared with the control, Treatment 1 irrigation water had minimal impact on cotton growth, with cotton yield decreasing by only 11.85%. Irrigation water productivity decreased with increasing irrigation water salinity, with Treatment 1 showing the smallest reduction relative to the control. Under different brackish water treatments, soil salinity in the 10–40 cm layer exhibited cumulative effects, with the control showing a 14.08% increase in soil salinity after the final irrigation compared with pre-irrigation levels, while Treatment 5 exhibited the greatest salinity increase at 173.08%. In conclusion, irrigation water with a salinity of 2.36–3.39 $g \cdot L^{-1}$ (Treatment 1) had minimal effects on cotton growth, yield, water productivity, and soil salinity. Therefore, employing appropriately mixed brackish water irrigation during drought and water shortage periods can effectively alleviate regional water resource constraints and ensure cotton production.

Keywords: brackish water; cotton; yield; mulched drip irrigation; salinity; southern Xinjiang

1 Introduction

Southern Xinjiang (hereinafter referred to as "Southern Xinjiang") experiences a temperate extreme continental climate characterized by aridity, low rainfall, abundant sunlight, and high evaporation. Water scarcity represents the primary constraint on agricultural development in this region. However, Southern Xinjiang possesses substantial shallow saline groundwater and irrigation drainage resources that are readily accessible and utilizable. As a salt-tolerant crop, cotton has become the mainstay of the regional economy. Consequently, the rational use of brackish water for cotton irrigation offers a critical solution to the imbalance between water and land resources.

Extensive research has investigated the relationship between brackish water and crop growth and yield, providing theoretical support for its appropriate utilization. Studies have shown that increasing irrigation water salinity reduces seed germination rates, decreases leaf area index, reduces plant height, diminishes dry matter accumulation, and decreases root area. As salt stress intensifies and persists, cotton photosynthetic physiological indicators decline, the growth period shortens, and both boll number per plant and single boll weight decrease significantly, ultimately causing yield reductions. Regardless of irrigation method, soil salinity increases and yields decline. However, some scholars argue that low-salinity brackish water does not adversely affect cotton growth and may even have salt-leaching effects while providing beneficial trace elements that effectively promote growth. Therefore, to explore regional cotton responses to salinity, pursue rational brackish water utilization methods, and elucidate crop physiological-ecological response mechanisms under brackish water irrigation, this study selected cotton—the primary economic crop in Southern Xinjiang—as the research subject for field experiments. The objective is to provide scientific support for the development and utilization of underground saline water resources and the sustainable development of irrigated agriculture in this region.

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2 Materials and Methods

2.1 Experimental Site Description

The experiment was conducted at a site located at 88°30 E, 42°20 N in the Xinjiang Production and Construction Corps. Situated in the Tarim Basin, the area features a warm temperate continental desert climate with hot, dry summers and long, cold winters. The region experiences frequent dry, hot winds, particularly during spring when low vegetation cover leads to dust storms that adversely affect crop growth. Precipitation is scarce, with low annual averages and intense evaporation, though the long frost-free period is suitable for cotton cultivation. The regiment' s cultivated land consists of sandy loam with poor water retention and storage capacity, unable to meet normal crop water requirements during the growing season, representing a typical arid irrigated agricultural area.

2.2 Experimental Design and Irrigation Management

The experiment employed a "one film, two drip tapes, four rows"planting pattern with a plant spacing of 10 cm and film width of 125 cm [Figure 1: see original paper]. Drip tapes were laid in the wide rows [Figure 125: see original paper]. Six treatments were established with different freshwater/saline water ratios: 1:0 (control, mineralization degree 0.75 $g \cdot L^{-1}$); 4:1 (Treatment 1, mineralization degree 3.39 $g \cdot L^{-1}$); 3:2 (Treatment 2, mineralization degree 5.51 $g \cdot L^{-1}$); 2:3 (Treatment 3, mineralization degree 7.74 $g \cdot L^{-1}$); 1:4 (Treatment 4, mineralization degree 9.32 $g \cdot L^{-1}$); and 0:1 (Treatment 5, mineralization degree 11.81 $g \cdot L^{-1}$). Each treatment was replicated three times. During the seedling stage, small amounts of freshwater were applied to ensure normal cotton growth, after which brackish water was used from the budding stage onward. The experiment utilized gravity-fed drip irrigation [Figure 2: see original paper]. Freshwater and saline water were pumped into a 20 m^3 mixing tank at different proportions, thoroughly mixed, and then delivered to each plot. The total irrigation amount was 5250 $m^3 \cdot hm^{-2}$ across 11 irrigation events during the growth period, with specific irrigation ratios and amounts for each growth stage detailed in Table 1 . Fertilizer application and agronomic practices followed local recommendations.

2.3 Measurement Indicators

2.3.1 Growth Indicators In each experimental plot, three uniformly growing plants in the inner rows were selected as representative observation subjects and marked. Plant height and leaf area were measured using a steel tape, stem diameter with an electronic digital caliper, and boll and fruit branch numbers through direct counting. Measurements were taken every 7 days, totaling 19 measurements throughout the growth period.

2.3.2 Chlorophyll Content Determination Beginning from the budding stage, three consistent plants were selected from each plot. Chlorophyll content was measured in situ on functional leaves using a SPAD-502 chlorophyll meter (Konica Minolta Sensing, Inc., Japan). Three measurements were taken per plant and averaged, with values from three plants per plot then averaged to represent the plot' s chlorophyll content.

2.3.3 Cotton Dry Matter and Yield Determination During different growth stages, three cotton plants were randomly sampled from each plot and oven-dried at 105°C to constant weight for dry matter measurement. At the boll opening stage, three 6.67 m^2 areas of uniform growth were selected per treatment to count bolls, after which cotton was harvested, sun-dried, and weighed to calculate seed cotton yield. The mean of three replicates represented each treatment' s yield, which was then converted to per-hectare yield.

2.4 Data Processing and Analysis

Data were organized using Excel, plotted with Sigmaplot 10.0, and analyzed for significance using SPSS 19.0.

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3 Results and Analysis

3.1 Effects on Cotton Growth Indicators

3.1.1 Plant Height and Stem Diameter Figure 3 [Figure 3: see original paper] shows that cotton plant height growth patterns were consistent across treatments, with rapid early growth during the vegetative stage, slowing after topping, and stabilization by the boll opening stage. To ensure normal seedling growth with minimal water requirements, freshwater was applied during the seedling stage, resulting in negligible height differences among treatments. From seedling to flowering, growth rates were: control 1.59 $cm \cdot d^{-1}$; Treatment 1 1.38 $cm \cdot d^{-1}$; Treatment 2 1.22 $cm \cdot d^{-1}$; Treatment 3 1.40 $cm \cdot d^{-1}$; Treatment 4 1.14 $cm \cdot d^{-1}$; and Treatment 5 1.04 $cm \cdot d^{-1}$. After topping, height growth slowed, reaching final heights of 83.05 cm (control), 79.50 cm (Treatment 1), 71.83 cm (Treatment 2), 66.50 cm (Treatment 3), 60.50 cm (Treatment 4), and 57.50 cm (Treatment 5). Analysis revealed that increasing irrigation water salinity restricted growth rates, with height differences among treatments becoming more pronounced as salinity increased.

Stem diameter changes were consistent across treatments, increasing throughout the growth period. The transition from seedling to peak budding featured rapid vegetative growth, resulting in faster stem thickening. During later growth stages, concurrent vegetative and reproductive growth prioritized reproductive organ development, reducing stem thickening. By the boll opening stage, the control exhibited the maximum stem diameter of 11.16 mm, followed by Treatment 1 at 11.25 mm. Compared with the control, Treatment 5 showed the greatest reduction at 20.40% (8.96 mm), attributable to higher salt input, while Treatment 1 showed the smallest reduction.

3.1.2 Leaf Area Index Figure 4 [Figure 4: see original paper] illustrates that brackish water effects on leaf area index (LAI) followed a unimodal pattern across the growth period. From seedling to boll stage, LAI increased as cotton underwent vegetative growth with increasing fruit branches and leaves, peaking at the boll stage. From boll to opening stage, water and nutrients prioritized reproductive growth, causing lower leaf senescence and gradual LAI reduction. During the seedling and budding stages, despite fewer irrigation events, cotton' s low salt tolerance resulted in negative salinity effects, causing Treatment 5' s LAI to fall below other treatments. At the boll stage, LAI peaked, with the control reaching 3.41, significantly higher than Treatments 1-5. During the opening stage, increased irrigation frequency introduced more salts, creating significant

LAI differences among treatments. The control showed the highest LAI, exceeding Treatments 1 and 2 by 0.52% and 0.39%, respectively, and Treatments 3-5 by 34.38%, 48.31%, and 46.73%. LAI consistently decreased with increasing irrigation water salinity, indicating salt inhibition of leaf growth.

3.1.3 Chlorophyll Content Figure 5 [Figure 5: see original paper] shows that SPAD values across treatments followed a consistent pattern of initial increase followed by decrease, reaching minima at flowering and maxima at the boll stage, then declining after boll opening. SPAD values primarily ranged between 40-55. At flowering, SPAD values increased with irrigation water salinity, with Treatments 1 and 2 exceeding the control by 8.13% and 18.23%, respectively. At boll opening, all treatments except Treatment 1 showed declining SPAD values relative to the control, with Treatments 2-5 decreasing by 4.61%, 10.28%, 3.41%, and 9.08%, respectively. During early growth stages, low salt concentrations promoted growth and increased SPAD values. However, as the growth period progressed and irrigation frequency increased, higher salinity introduced more salt into the soil profile, causing salt stress that gradually reduced chlorophyll content. These results indicate that SPAD values are influenced by both growth stage and salt stress.

3.1.4 Cotton Dry Matter Accumulation Figure 6 [Figure 6: see original paper] demonstrates that single-plant dry matter accumulation across treatments showed an increasing trend throughout the growth period, with slower accumulation before budding and accelerated increase after budding, peaking at boll opening. Dry matter accumulation decreased with increasing irrigation water salinity. During seedling and budding stages, differences among brackish water treatments were insignificant due to low water requirements, good soil moisture conditions, and minimal salt input. During flowering and boll stages, dry matter accumulation decreased with increasing salinity, with the control reaching maximum accumulation of 41.34 $g \cdot plant^{-1}$, followed by Treatments 1-5 at 34.33, 29.36, 27.18, 24.36, and 21.45 $g \cdot plant^{-1}$, respectively. At boll opening, the control maintained the highest dry matter weight, with significant declines observed as irrigation water salinity increased. Although all treatments showed increasing dry matter accumulation throughout the growth period, the control consistently exhibited higher growth rates than other treatments, with smaller increases observed at higher salinity levels.

3.2 Cotton Yield and Irrigation Water Productivity

Yield measurements at maturity showed single boll weights ranging 4.5-5.5 g across treatments without significant differences. However, boll number per plant decreased significantly with increasing salinity. Table 2 reveals that cotton yield decreased progressively with increasing saline water proportion. The control (freshwater) achieved the highest yield at 6835.50 $kg \cdot hm^{-2}$, while Treatment 5 (full saline water) produced the lowest yield at 2755.65 $kg \cdot hm^{-2}$, approximately 40.3% of the control. Treatment 1 yield was 6025.95 $kg \cdot hm^{-2}$, representing only an 11.85% reduction from the control. Irrigation water productivity decreased with increasing salinity, with the control achieving the highest efficiency at 1.30 $kg \cdot m^{-3}$. Treatment 1 productivity was 1.15 $kg \cdot m^{-3}$, an 11.5% reduction, while Treatment 5 showed the lowest productivity at 0.52 $kg \cdot m^{-3}$, a 60% decrease. For the same irrigation quota, costs decreased with increasing salinity due to reduced freshwater requirements.

3.3 Soil Salinity Accumulation in 10-40 cm Layer

Table 3 presents soil salinity accumulation data. Before the first irrigation, soil salinity showed no significant differences among treatments, ranging 0.70-0.80 $mS \cdot cm^{-1}$. After the final irrigation, salinity increased significantly with irrigation water salinity, with the control showing the smallest increase to 0.81 $mS \cdot cm^{-1}$ and Treatment 5 reaching the maximum at 2.13 $mS \cdot cm^{-1}$. All treatments exhibited increased salinity after the final irrigation compared with pre-irrigation levels, with the control increasing by 14.08% and Treatments 1-5 increasing by 58.57%, 69.86%, 104.23%, 118.75%, and 173.08%, respectively. These results demonstrate that even freshwater irrigation leads to salt accumulation, though brackish water irrigation accelerates this process substantially.

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4 Discussion

Previous research by Wang et al. demonstrated that cotton height and stem diameter growth are inhibited under high soil salinity conditions, consistent with our findings that increasing irrigation water salinity and frequency intensified salt stress, reducing plant height, stem diameter, and leaf area while advancing growth stages and promoting leaf senescence. Water availability is a critical factor controlling plant height, with adequate water and fertilizer promoting better growth. Although cotton is salt-tolerant, salt stress significantly impacts growth by inhibiting water uptake.

Chlorophyll content serves as an important biochemical parameter reflecting vegetation growth stage and nutritional status. Our results showed that chlorophyll relative content increased during flowering but decreased at boll opening with increasing irrigation water salinity, differing from some previous studies. This discrepancy may arise because chlorophyll content is influenced by multiple factors including growth stage, growth rate, management practices, and salt stress, requiring further investigation.

Cotton dry matter forms the foundation of yield formation. Research by Song et al. and Yang et al. found that irrigation water mineralization below 2.0 $g \cdot L^{-1}$ had minimal impact on single-plant dry matter accumulation and could even be stimulatory, while exceeding this threshold progressively reduced accumulation. Our findings align with these results, confirming that salinity inhibits dry matter accumulation in a concentration-dependent manner.

Studies by Li et al. and others have shown that cotton yield under saline irrigation does not differ significantly from freshwater irrigation when mineralization is below 3.38 $g \cdot L^{-1}$, but yields decline linearly beyond this threshold. Our results with Treatment 1 (3.39 $g \cdot L^{-1}$) showing only an 11.85% yield reduction are consistent with these findings. The observed decrease in irrigation water productivity with increasing salinity also corroborates previous research.

Soil salinity accumulation occurred across all treatments, with the control showing a 14.08% increase and Treatment 5 a 173.08% increase. These results indicate that even freshwater irrigation causes salt accumulation, though brackish water irrigation exacerbates the problem. Therefore, controlling irrigation water salinity and determining appropriate freshwater/saline water ratios are essential to minimize soil salinization and yield reduction. Research suggests that magnetized water irrigation or open-ditch drainage can reduce soil salt content, offering potential strategies for brackish water utilization.

This experiment was conducted over a single year, and the short experimental period limits conclusions about long-term effects of brackish water irrigation on cotton growth, yield, and soil physicochemical properties, warranting further investigation.

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5 Conclusions

Based on experiments with different brackish water ratios, analysis of cotton salinity responses, and salt accumulation patterns in cotton fields, the following conclusions were drawn:

1) Increasing irrigation water salinity significantly inhibited cotton growth, reducing plant height, stem diameter, chlorophyll content, and single-plant dry matter accumulation.
2) Cotton yield decreased with increasing irrigation water salinity. Treatment 1 (freshwater/saline ratio 4:1, salinity 3.39 $g \cdot L^{-1}$) had minimal impact on cotton growth, with yield decreasing by only 11.85% compared with the control. Irrigation water productivity and freshwater requirements decreased with increasing salinity, reducing per-hectare freshwater costs.
3) After the growth period, soil salinity in the 10–40 cm layer increased after irrigation across all treatments. Treatment 1 resulted in relatively minor soil salinity increases, demonstrating that brackish water irrigation at this salinity level is feasible.

In summary, using appropriately mixed brackish water irrigation during drought periods can effectively alleviate regional water shortages and ensure cotton production sustainability.

References

[1] Ma L J, Hou Z A, Min W, et al. Drip irrigation with suitable saline water improves water use efficiency for cotton[J]. Transactions of the Chinese Society of Agricultural Engineering, 2013, 29(14): 130-138.

[2] Zhang J P, Feng D, Zheng C L, et al. Effects of saline water irrigation on soil water-heat-salt variation and cotton yield and quality[J]. Transactions of the Chinese Society of Agricultural Machinery, 2014, 45(9): 161-167.

[3] Dong Y J, Chen W F, Wang W C, et al. Effects of brackish water irrigation under different NaCl concentrations on physiological characteristics of cotton seedlings[J]. Soils, 2017, 60(6): 1140-1145.

[4] Hu S J, Shen Y J, Chen X L, et al. Effects of saline water drip irrigation on soil salinity and cotton growth in an Oasis Field[J]. Ecohydrology, 2013, 6(6): 1021-1030.

[5] Qadir M, Shams M. Some agronomic and physiological aspects of salt tolerance in cotton (Gossypium hirsutum L.)[J]. Journal of Agronomy and Crop Science, 2008, 179(2): 101-106.

[6] Zhu Y K, Wang Z H, Li W H, et al. Effects of different salt stress on physiological growth and yield of cotton under drip irrigation[J]. Journal of Soil & Water Conservation, 2018, 32(2): 298-305.

[7] Sadeh A, Ravina I. Relationships between yield and irrigation with low-quality water: A system approach[J]. Agricultural Systems, 2000, 64(2): 99-113.

[8] Feng G X, Zhang Z Y, Wan C Y, et al. Effects of saline water irrigation on soil salinity and yield of summer maize (Zea mays L.) in subsurface drainage system[J]. Agricultural Water Management, 2017, 193: 205-213.

[9] Mantell A, Frenkel H, Meiri A. Drip irrigation of cotton with saline-sodic water[J]. Irrigation Science, 1985, 6(2): 95-106.

[10] Qadir M, Shams M. Influences of sodium chloride on ion accumulation, yield components, and fibre characteristics in salt-tolerances and salt-sensitive lines of cotton (Gossypium hirsutum L.)[J]. Field Crops Research, 2000, 66(2): 115-127.

[11] Ashraf M, Ahmad S, Ashraf M. Salt tolerance of cotton: Some new advances[J]. Critical Reviews in Plant Sciences, 2002, 21(1): 1-30.

[12] Zhang W F, Li M C. Study on dry matter accumulation and distribution law of high-yield cotton in northern Xinjiang[J]. Xinjiang Farm Research of Science and Technology, 1997, 20(6): 1-2.

[13] Min W, Guo H J, Zhou G W, et al. Soil salinity, leaching, and cotton growth as affected by saline water drip irrigation and N fertigation[J]. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science, 2016, 66(6): 1-13.

[14] Thind H S, Buttar G S, Aujla M S. Yield and water use efficiency of wheat and cotton under alternate furrow and check-basin irrigation with canal and tube well water in Punjab, India[J]. Irrigation Science, 2010, 28(6): 489-496.

[15] Song Y X, An J Q, He A R, et al. Effect of mulched drip irrigation with saline water on cotton growth and yield[J]. Research of Soil and Water Conservation, 2016, 23(1): 128-132.

[16] Yang C J, Luo Y, Sun L, et al. Experimental study on the impacts of the irrigation water salinity on cotton growth in Manas River Oasis, Xinjiang[J]. Resources Science, 2012, 34(4): 660-667.

[17] Wang J S, Wang L, Yao B L, et al. Study on soil water and salt effects on cotton growth with light-saline water drip irrigation under mulching[J]. Water Saving Irrigation, 2012, 37(12): 9-15.

[18] Zhang Y, Zhu Z, Cai D S. The effect of the growth and yield of cotton in arid land under-mulch drip irrigation with salt water[J]. China Rural Water and Hydropower, 2015, 57(9): 106-110.

[19] Hong S, Zhang Z, Zhang L F, et al. Hyperspectral estimation model of chlorophyll content in cotton canopy leaves under drip irrigation at different growth stages[J]. Cotton Science, 2019, 31(2): 138-146.

[20] Xin C S, Dong H Z, Tang W, et al. Effects of coastal saline soils with different fertility on plant growth and development as well as physiological characteristics in cotton[J]. Cotton Science, 2007, 19(2): 124-128.

[21] Li K M, Liu H G, Shi P J, et al. Simulation of soil water and salt migration under open-ditch drainage[J]. Arid Zone Research, 2018, 35(6): 1299-1307.

[22] Li X, Qiao M, Zhou S B. Effects of drip irrigation with magnetized water on soil desalinization in cotton field and cotton yield[J]. Arid Zone Research, 2017, 34(2): 431-436.

[23] Jiang J, Feng S Y, Wang Y S, et al. Effect of irrigation water quantity and quality on water-salt distribution and evapotranspiration of spring maize[J]. Scientia Agricultura Sinica, 2010, 43(11): 2270-2279.

[24] Li K J, Ma J Y, Cao C Y, et al. Effect of irrigation water salt content on cotton growth and yield[J]. Chinese Journal of Eco-Agriculture, 2011, 19(2): 312-317.

[25] Huang J O, Jin M G, Li X W. Influence of mulched drip-irrigation with brackish water on element composition of soil, cotton, and cotton yield[J]. Earth Science: Journal of China University of Geosciences, 2014, 39(6): 751-759.

[26] Zhang J P, Feng D, Cao C Y, et al. Effects of irrigation with saline water on growth and water use efficiency of film-mulched cotton plant[J]. Journal of Drainage and Irrigation Machinery Engineering, 2014, 32(5): 448-455.

[27] Tang C C, Zhang K, Zhou X, et al. Effects of drip irrigation under brackish water film on changes of soil salt isolates and maize yield[J]. Science & Technology Vision, 2017(6): 57-58.

[28] Zhang J P, Feng D, Zheng C L, et al. Effects of saline water irrigation on soil water-heat-salt variation and cotton yield and quality[J]. Transactions of the Chinese Society of Agricultural Machinery, 2014, 45(9): 161-167.

Note: Figure translations are in progress. See original paper for figures.