Effects of brackish water irrigation on Photosynthesis and yield of Winter Wheat

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Abstract. In this paper, winter wheat was used as the research object. The chlorophyll content, net photosynthetic rate, light response curve and yield of winter wheat were compared with the experimental data from 2015 to 2017. The results show that: The brackish water of 3g/L has little effect on chlorophyll content. The physiological growth of winter wheat could be promoted by irrigation with 3 g/L brackish water at jointing stage, and photosynthesis could be promoted by appropriate salt stress. Salt stress can change the way crops use effective light radiation. The brackish water of 3g/L can promote the utilization efficiency of low effective light radiation in winter wheat. The brackish water of 5g/l will affect the leaf structure of winter wheat, reduce the response of leaves to high effective light radiation, and eventually lead to the decline of photosynthesis. Two years of brackish water irrigation will have a certain effect on crop yield.

1. Introduction
The shortage of fresh water resources is a worldwide problem to be solved urgently. Relevant studies have shown that saline water or brackish water has a certain buffer capacity to soil. It is entirely possible to achieve the effect of drought resistance and yield increase by rational use of brackish water resources[1,2]. The groundwater in the Yellow River Delta is mainly saline water and brackish water. Winter wheat is a moderate salt-tolerant crop and is one of the main crops in the Yellow River Delta. In this paper, winter wheat was selected as the research object to explore the effect of two years continuous brackish water irrigation on winter wheat. Previous studies have shown that when soil salinity is lower than the crop salt tolerance threshold, there is no harm to crop growth, and when soil salinity is higher than the plant salt tolerance threshold, it will be affected[3,4]. But salt stress, especially high concentration (400 mmol.L⁻¹) NaCl, can cause various adverse effects on plant photosynthesis[5]. At the leaf scale, brackish water irrigation has certain effects on chlorophyll content, net photosynthesis, light response fitting curve, etc. Long-term continuous use of brackish water irrigation will lead to a decline in winter wheat yield [6]. In this paper, the photosynthetic characteristics of Winter Wheat under brackish water irrigation were studied by field experiment, in order to provide scientific basis for formulating local brackish water irrigation system and sustainable development of irrigation agriculture.

2. Materials and methods

2.1 Study area
The test area is located in Xia Wa Town, Zhanhua District, Binzhou City, Shandong Province. The topography is high in the southwest and low in the northeast. The elevation above the beach is
1.6-8.4 meters (Yellow Sea elevation). North latitude 37 degrees 34’, east longitude 117 degrees 45’. The climate in this area belongs to temperate monsoon climate zone, with an average annual sunshine hours of 2690.3 hours and an average annual temperature of 12 degrees Celsius. The precipitation is concentrated in June to August, The average precipitation is 376.6 mm.

2.2 Experimental design
The experiment was conducted at Xia Wa Town Experimental Station from 2015 to 2017. There was no significant difference in average temperature between the two years. The physical and chemical properties of soil were shown in Table 1. There are 4 treatments in the field test area, with 3 repetitions for each treatment and 12 plots. Each experimental plot has a size of 3 m×6 m, randomized block alignment; in order to avoid side leakage interference, a 0.5 m isolation belt is set up between the cells. Plastic film is used to vertically lay 1.5 m deep. The specific irrigation plan is shown in table 2.

![Fig 1 Barrel experiments area](image)

Table 1 Physical and chemical properties of soil

| Layer /cm | Bulk Density (g/cm³) | PH | Cl⁻/(g·kg⁻¹) | K⁺/(g·kg⁻¹) | Na⁺/(g·kg⁻¹) | total salt content/(g·kg⁻¹) | Soil properties |
|-----------|----------------------|----|--------------|------------|-------------|-----------------------------|----------------|
| 0~20      | 1.39                 | 7.3| 0.51         | 0.1        | 0.14        | 1.36                        | Loam           |
| 20~40     | 1.33                 | 7.13| 1.95         | 0.08       | 0.24        | 2.86                        | Sandy loam     |
| 40~60     | 1.32                 | 7.07| 0.76         | 0.08       | 0.23        | 1.56                        | Sandy loam     |
| 60~80     | 1.36                 | 7.03| 0.25         | 0.07       | 0.12        | 0.78                        | Loamy sand     |
| 80~100    | 1.46                 | 7.03| 0.27         | 0.06       | 0.14        | 0.85                        | Loam           |

Table 2 Experimental scheme of brackish water irrigation for winter wheat

| Irrigation treatment | Irrigation quota/mm | reviving stage~jointing stage/mm | jointing stage~heading stage/mm | heading~grainfilling stage/mm |
|---------------------|---------------------|----------------------------------|---------------------------------|-------------------------------|
| T1                  | 240                 | 80 (freshwater)                  | 80 (freshwater)                 | 80 (freshwater)              |
| T2                  | 160                 | 80 (freshwater)                  | 80 (freshwater)                 | 0                             |
| T3                  | 240                 | 80 (freshwater)                  | 80 (3 g/L brackish water)       | 80 (3 g/L brackish water)    |
| T4                  | 160                 | 80 (freshwater)                  | 80 (3 g/L brackish water)       | 0                             |

2.3 Observation contents and methods
Chlorophyll content: chlorophyll content of wheat leaves was determined by SPAD-502. Leaf functional leaves were measured before heading, and flag leaves were determined after heading.

Photosynthetic characteristics: The photosynthetic rate was measured by LCpro + automatic portable photosynthetic measurement system. After winter wheat rejuvenation, sunny weather was
selected for every growth period, and 8:00~18:00 was measured 1 times every 2 hours.

Plant height: marked height observation. Before heading, the plant height is the height from the ground to the highest leaf tip; after heading, the plant height is the height from the ground to the top of the ear.

Dry matter on the ground: Take 10 cm long representative plants, randomly take three of them, the shoot and root were separated, in the oven at 105°C for 30 minutes, cooling to 70°C for 48 hours to determine the dry matter weight on the ground.

Production Measurements: The number of grains per spike was calculated by randomly selecting 30 ears; The random number 3 of 1000 grain determination of 1000-grain weights; the error between 1000 grains per treatment was less than 0.1 g; after maturity, the yield of all plots was harvested by plot combine.

2.4 Data processing
The test data were sorted and plotted by Excel. Data correlation and significant difference were analyzed by SPSS19.0 for the data relationship between different treatments of the same index.

3. Results and discussion

3.1 Effect of brackish water irrigation on chlorophyll content

Fig. 2 is the average chlorophyll content measured before and after three irrigation in 2016 and 2017, and the chlorophyll content of each treatment showed the same upward regularity until the early jointing stage. After secondary irrigation, after two irrigation, the chlorophyll content of T1 and T2 increased fastest, while T3 and T4 increased slowly. Therefore, brackish water irrigation at jointing stage has little effect on the maximum chlorophyll content, but it will affect the rate of chlorophyll content increase. When winter wheat leaves enter the grain filling stage, the leaf chlorophyll content of winter wheat decreased gradually during the senescence stage. Brackish water irrigation during filling stage can promote chlorophyll production to a certain extent. Compared with the data of 2016 and 2017, the chlorophyll content in 2017 was lower than that in 2016. The reason was that two years of brackish water irrigation resulted in the accumulation of soil salinity, which affected the growth of crops.

![Fig 2 Change of SPAD value in each treatment](image)

3.2 Effect of brackish water irrigation on net photosynthetic rate of Winter Wheat

The average net photosynthetic rate (Pn) of Winter Wheat during 8:00-18:00 was analyzed. Fig. 3. In 2016, the net photosynthetic rate of all treatments increased gradually from heading stage to grain filling stage, and then decreased gradually with leaf senescence at milk ripening stage. This indicates that brackish water has little effect on net photosynthesis. In 2017, the net photosynthesis of T1 T2 increased first and then decreased due to no use of brackish water irrigation. However, T3 T4 was irrigated with brackish water for two consecutive years, and net photosynthesis began to decrease gradually after flowering. T4 was affected by both salinity and water stress, and its net
photosynthetic rate decreased most rapidly.

Fig 3 Net photosynthetic rate in each treatment

3.3 Effect of brackish water irrigation on light response of Winter Wheat
Farquhar model with non-right-angled hyperbola was used to fit, and the determination coefficients R2 were all above 0.99. The fitting results were shown in Figure 5. The net photosynthetic rates of T3 and T4 were significantly lower than those of T1 and T2. Compared with T1 and T3, Winter Wheat under normal irrigation had higher photosynthetic capacity. Long-term salt environment accelerated the senescence of winter wheat, and the stimulation of salt on cell photosynthetic activity could not compensate for the photosynthetic loss caused by cell senescence. The maximum net photosynthetic rate of T2 was lower than that of T4, but the quantum efficiency at the light compensation point increased to some extent, which indicated that the presence of salt could compensate for the decrease of photosynthetic capacity of Winter Wheat under the condition of water deficiency.

Fig 4 Effects of different treatments on light response curves

3.4 Effects of brackish water with different salinity on yield, dry matter and root system of Winter Wheat

Table 3 Yield, dry matter and plant height of Winter Wheat under different salinity

| Year     | Treatment | Spike number (1m²) | Grain number of single spike | KTW (g) | Square yield (kg) | Field yield/kg | Dry matter (g/plant) | Plant height (cm) |
|----------|-----------|-------------------|-----------------------------|---------|------------------|---------------|----------------------|-------------------|
| 2015-16  | T1        | 43.625a           | 45.89a                      | 1.02a   | 19.76a           | 15.17a        | 77.013a              | 43.625a           |
|          | T2        | 42.658a           | 44.98a                      | 0.9a    | 16.19b           | 14.11b        | 74.333b              | 42.658a           |
|          | T3        | 39.375ab          | 45.8                        | 0.94b   | 18.6a            | 15.8a         | 75.333b              | 39.375ab          |
Theoretical yield (kg/hm²) = efficient panicle number (10000 spike /hm²) × grain number per panicle (grain / spike) × 1000 grain weight (g) × 10⁻². The effect of different salt water utilization on yield and yield components is shown in Table 3. From the results of two years, we can see that in 2016, T2 decreased by 18.1% compared with T1, T4 decreased by 14% compared with T3, T3 decreased by 5.9% compared with T1, and T4 decreased by 1.1% compared with T2. In 2017, T2 decreased by 17.9% than T1, and 8.7% decreased compared with T3. In 2016, dry matter was treated with dry matter T1 > T3 > T2 > T4 in T3 > T1 > T4 > T2 2017 filling period, and plant height, T3 and T4 treatment decreased by 7.7% and 7.3% in 2017, compared with T1 and T2 treatment in 2016. Brackish water irrigation will reduce the yield and agronomic traits of winter wheat, but the yield of brackish water is smaller than that of fresh water irrigation.

4. Conclusion

(1) Brackish water of 3g/L's irrigation would not have a great influence on the chlorophyll content in the leaves, and the chlorophyll function in the leaves remained intact under low salinity stress.

(2) Based on the net photosynthesis and light response curve fitting, we found the brackish water of 3g/L can promote the utilization efficiency of crops to low light intensity.

(3) For two years of brackish water irrigation for two years, the output of second years has decreased more than that in the first year. One reason is that there are more factors in the field experiment; On the other hand, the impact of salt accumulation on crops has expanded for two consecutive years. If the brackish water is used for irrigation for a long period, it is necessary to make more. A reasonable irrigation system for brackish water is added.

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