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Effects of Different Water Stress Potential at Ripening Stage on Rice Yield and Physiological Traits in Saline-alkali Soil

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Abstract: To explore the effects of different soil water potential of ripening stage on rice yield and physiological traits in saline-alkali soil, using four treatment levels of soil water potential of 0 kPa (H1: soil moisture), soil water potential of -15 kPa (H2), soil water potential of -30 kPa (H3), and CK (continuously flooded), a comparative study of different soil water potential of ripening stage on grain yield, dry matter production, and leaf physiological treats were conducted. The results showed that the soil water control of rice dough stage in the soda saline soil, grain yield showed the trend of A (0kPa) > CK (water layer), B (-15 kPa) > C (-30 kPa), A(0k Pa) compared with CK (water layer), B(-15kPa) and C(-30k Pa) were increased by 3.01%, 12.40%, 18.08%; total dry matter accumulation showed A (0kPa) > CK (water layer), B (-15kPa) > C (-30 kPa), A (0 kPa) is slightly higher than that of CK, no significant differences, A(0 kPa), CK(water layer) and B(-15k a), C (-30 kPa) reached a significant differences level ($p<0.01$); the increase of free proline content in leaves from high to low in the order of B > C > CK > A; the highest chlorophyll content was C, B content was the lowest, the chlorophyll content in the leaves was from high to low order C> CK > A> B; the highest level of LRWC was CK, the average of 49.65% for two years, the of LRWC for two years showed CK> A> B > C trend; The LAI trend of each treatment on September 10, September 15 and September 20 was basically the order of CK> A> B> C. The soda saline alkali soil rice dough stage field should be moisturizing state (0kPa).

Introduction

China's population is expected to reach 1.6 billion by 2030, when China will face a severe water crisis and huge population pressure. Relying on traditional technology cannot fundamentally solve the contradiction between supply and demand of agricultural water and ensure food security, so agricultural water-saving should be improved to a strategic height, deep and lasting, unremitting to the end. China is the largest rice producing country in the world. Rice water consumption is the largest in crops, and its water consumption accounts for 54% of the total water consumption, accounting for more than 65% of the total agricultural water consumption[1].Jilin Province as a major high-quality japonica rice producing areas, rice area increased year by year, increased demand for water resources[2].The ecological problem of saline soil with more serious soil barren, salinization is becoming more and more serious, the annual evaporation is far greater than the precipitation, the shortage of water resources, the deterioration of the ecological environment and a serious threat to crops, especially the development of rice production. The Songnen Plain in Jilin

Province is one of the three major distribution areas in China, reaching 1.7 million hm^2, accounting for 34% of the total area of the Songnen Plain. And rice is one of the best crops to improve salinization, because the cultivation of rice requires a lot of water, field water infiltration can salt under pressure[3].With the growth of population, the development of cities and industries, the change of global climate and the increase of environmental pollution, the increasingly scarce water resources for crop irrigation have seriously threatened the production of crops, especially the development of rice production[4,5]. How to maintain high yield of rice and even further increase production under limited water resources? This is an urgent issue in agricultural production. Previous studies have shown that moderate water conditions are beneficial to improve crop water use efficiency[6-8]. As the water-saving irrigation has become the difference between the experimental methods, the water treatment and the soil type, the influence of the soil water potential on the growth and development of rice and the related conclusions of the physiological mechanism are not exactly the same[9-12]. So far in the soda salted soil on the implementation of water-saving rice-related research data rarely. In this paper, the effects of different soil water potentials on the growth and development characteristics and yield of soda salted rice were studied in order to provide a scientific basis for the sustainable production of soda salted rice.

Materials and method

Materials

This test was conducted at test base of the modernization research institute of Jilin Agricultural University in 2011-2012,taking the high salty rice cultivar Changbai 9 as the test material.

The test soil type is soda salt soil, the values of pH, salinity, organic content, available N, available P and available K for the selected soil were 8.42, 0.23%, 1.89%, 158.8mg/kg、32.64mg/kg and 153.6mg/kg respectively.

Experimental design

We used pot methods in the rice ripening by manual control water processing. The expriment was conducted with 4 treatment levels: A moist, 0 kPa (soil water saturated soil water content 90%-100%), B -15 kPa C soil water potential, soil water potential of -30 kPa, in the ripening stage of rice to keep water as control (CK), CK for the rice growth process to keep the whole water, control water control for each period.

Two-year test process is basically the same, so we began to deal with water both on September 10 and survey data on September 18 . Test data are two-year average. In each treatment, 20 pots were embedded in the soil, and the upper part of the basin was flat with the ground.

Management method

Planted seedling pots with floor diameter 20 cm, upper diameter of 31 cm, 33 cm deep were installed 15 kg per pot dry soil. The base fertilizer were used a compound fertilizer with include15% N, 15% P_2O_5,and 15% K2O with per pot used 8.0g. The topdressing times on June 9, July 10 using urea 1.0 g per pot respectively. Forty-five day old seedlings were transplanted on May 24, into columns. During the test of fortification canopy, open sunny rain shed cloth, with waterproof cover to prevent greenhouse natural precipitation in the evening or rainy day, ensure the artificial control of water under the condition of other ecological factors close to natural conditions.

The phenotype of vacuum negative pressure soil moisture soil water potential in Nanjing Soil Research Institute of China production was measured, the buried depth of clay soil as head center distance 10 cm, 11:00, 14:00, 8:00 daily, 17:00 recorded negative pressure gauge, timely replenishment.

Sampled and measured

The content of free proline in leaves was determined by the method of three hydrate ketone, and the content of chlorophyll was determined by acetone and ethanol mixed extraction.

Leaf relative water content (RWC). Each treatments were pick 6flag leaf and packing by vacuum membrane. After weighing take these leaves to a vessel with containing distilled water and absorbing water saturated state, and in the 24 h later weighing again, fixing in bake oven and bake at 80 centigrade until constant weight.

RWC(%)=[(fresh weight-dry weight)/(water saturated state weight-dry weight)] ×100%

In September 18, 2 pots of rice plants were taken from each treatment, and roots were rinsed with water. The ground part of plant was separated by stem, sheath, leaf and spike. Beginning in 105 ℃ oven for 30 min, and then under the 80 ℃ drying to constant weight, weigh the dry weight of after cooling to room temperature.

After rice mature, 5 pots were taken for each treatment to measure yield. The number of effective panicles per panicle, grains per spike, panicle grain, unfilled grain number, 1000 -grain weight, seed setting rate, yield and so on.

Data processing

DPS V7.05 system software was used to analyze the data, and LSD (significant significant difference test) was used to compare the significance of the sample mean. This paper mainly takes the 2011 and 2012 two-year average for data analysis.

Results and analysis

Yield and its constituent factors

From Table1, it can be seen that different soil water potentials have a certain influence on the rice yield and yield traits of soda saline soil. The treatment of A 1000-grain weight, seed setting rate and yields were higher than other treatments, 1000-grain weight A> B> CK> C trend, treatment A higher than CK 3.78% higher than the treatment B and treatment C were 2.88% and 4.82%. The seed setting rate showed the treatment of A> CK> B> C, A and CK were not significant. The rice yield was treated A> CK>B> C trend, treatment A than treatment B yield 13.02% ($P < 0.05$), but there was no significant difference with CK. The panicle number and the number of grains per panicle were CK> A> B> treatment C trend.

Table 1 Effects of different soil water potential on yield and yield traits of rice

Treats	Year	Panicle number/ per basin	Grains per panicle	1000-grain weight /g	Seed setting percentage /%	Yield/ per basin·g
CK	2011	55.54	83.85	25.20	81.01	95.07
	2012	54.50	82.35	25.00	80.25	90.04
	Average	55.02aA	83.10aA	25.1bB	80.63abAB	92.53aAB
A	2011	53.78	82.02	25.82	81.00	92.25
	2012	54.28	83.24	26.28	82.90	98.44
	Average	54.03bA	83.13aAB	26.05aA	81.95aA	95.88aA
B	2011	51.93	81.48	25.11	78.90	83.83
	2012	52.71	79.62	25.53	80.11	85.83
	Average	52.32cB	80.55bBC	25.32bAB	79.5bB	84.83bBC
C	2011	52.92	79.96	24.49	76.30	79.07
	2012	52.46	80.40	25.21	77.51	82.42
	Average	52.69cB	80.18bC	24.85bB	76.90cC	80.73bC

Values followed by different letters are significantly different at $P< 0.05$.

The influence of dry matter accumulation

There were some differences in the dry matter accumulation of different soil water treatments(Table2). After 16 days of water treatment (August 25), the dry matter accumulation of stem and leaf of A, B and C rice plants was lower than CK in normal water - retaining layer, CK> A> B> C, But the dry matter accumulation of sheath was the highest, which was significantly higher than that of CK, A and B. The dry matter accumulation of panicle was CK> A> C> B, the difference between CK and A was not significant; the ear CK was the highest, followed by A, B was the lowest, and the difference between A and CK was not significant, C, this period of appropriate control of soil water potential is conducive to the transfer of rice stem and sheath material to the spike.

Table 2 Effects of different soil water potential on dry matter weight of rice

Stage	Part	year	CK	A	B	C
9.10	Stem g / hill	2011	12.29	10.95	10.25	8.98
		2012	11.91	11.27	10.75	9.43
		Average	12.10Aa	11.11Bb	10.50Bc	9.20Cd
	Leaf g / hill	2011	7.76	7.25	6.73	6.78
		2012	7.45	7.75	7.28	6.83
		Average	7.60Aa	7.50Aa	7.00ABb	6.80Bb
	Leaf sheath g / hill	2011	10.42	12.73	11.23	11.45
		2012	10.27	13.08	11.38	11.75
		Average	10.34Dd	12.90Aa	11.30Cc	11.60Bb
	Panicle g / hill	2011	37.80	33.48	27.03	29.38
		2012	36.78	33.93	27.38	29.83
		Average	37.29Aa	33.70Bb	27.20Dd	29.60Cc
	Root g / hill	2011	3.79	6.30	7.63	5.03
		2012	4.03	6.50	7.78	5.18
		Average	3.91Dd	6.40Bb	7.70Aa	5.10Cc
	Total dry matter g / hill	2011	72.06	70.70	62.85	61.60
		2012	70.43	72.52	64.55	63.00
		Average	71.24AB	71.61Aa	63.70Bc	62.30Cd

Values followed by different letters are significantly different at P< 0.05.

Effects on physiological characteristics of rice

The effect of proline content

Proline is the largest water-soluble amino acid, and has strong water binding capacity. When plants are subjected to water stress, its increase is beneficial to the water holding capacity of cells or tissues. From fig1 , the increase of free proline content in leaves from high to low in the order of B > C > CK > A, A, C and CK treatment had no significant difference, B treatment and CK treatment A and C had significant difference ($P < 0.05$), indicating rice in saline sodic soil with soil water potential decreased, leaf proline increased. As lower leaf water potential, thereby reducing the water potential difference between plants and environment, in order to save water and reduce the damage caused by soil water potential mitigation.

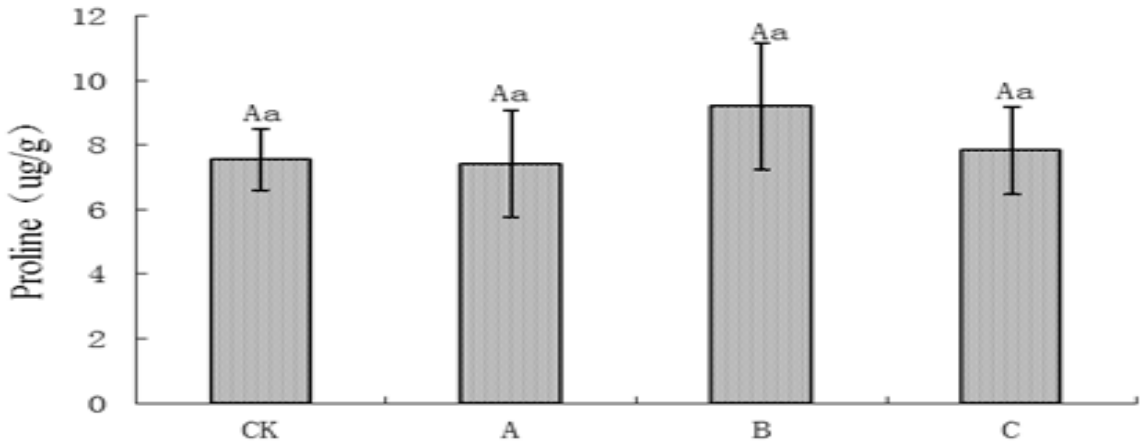

Fig. 1 Effects of different soil water potential on proline content of rice leaf

The effect of chlorophyll content

Chlorophyll is a material basis for photosynthesis of plants. The chlorophyll content is positively correlated with net photosynthetic rate, affected by nutrition, light and environmental conditions. From fig2, the highest chlorophyll content was C, B content was the lowest, the chlorophyll content in the leaves was from high to low order C> CK > A> B. The results showed that different water potentials of soda saline soil had a certain influence on chlorophyll content.

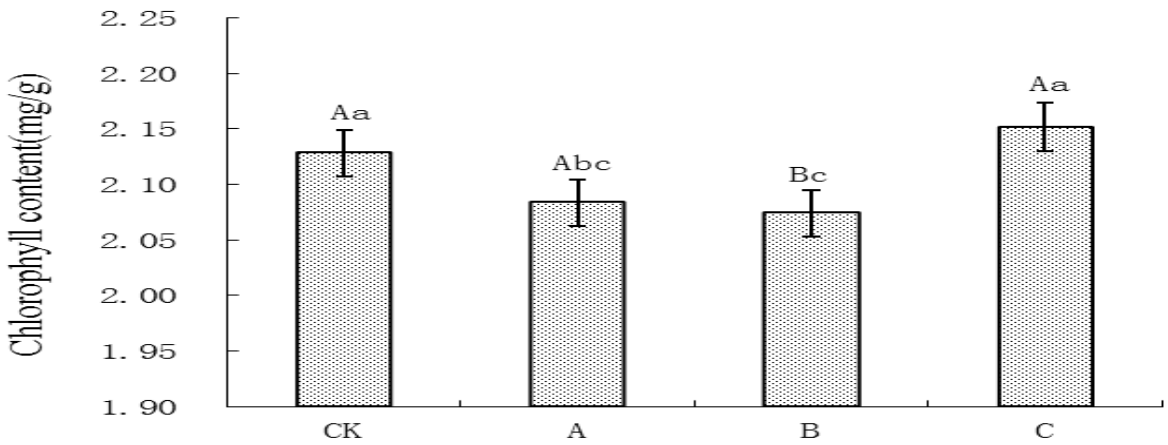

Fig.2 Effects of different soil water treatments on chlorophyll content of rice leaf

The effect of relative moisture content in rice leaves

From figure3, the significant effects of different soil water potentials on the relative water content of leaves in the salted soil of soda saline soil. During the water stress, the relative water content of leaves decreased rapidly, and the decrease was consistent with the degree of stress. After treatment, the highest level of LRWC was CK, the average of 49.65% for two years, the lowest level of LRWC was C, the average of 45.18% for two years, CK> A> B > C trend, CK and treatment A difference was not significant, CK and B, C differences were significant levels.

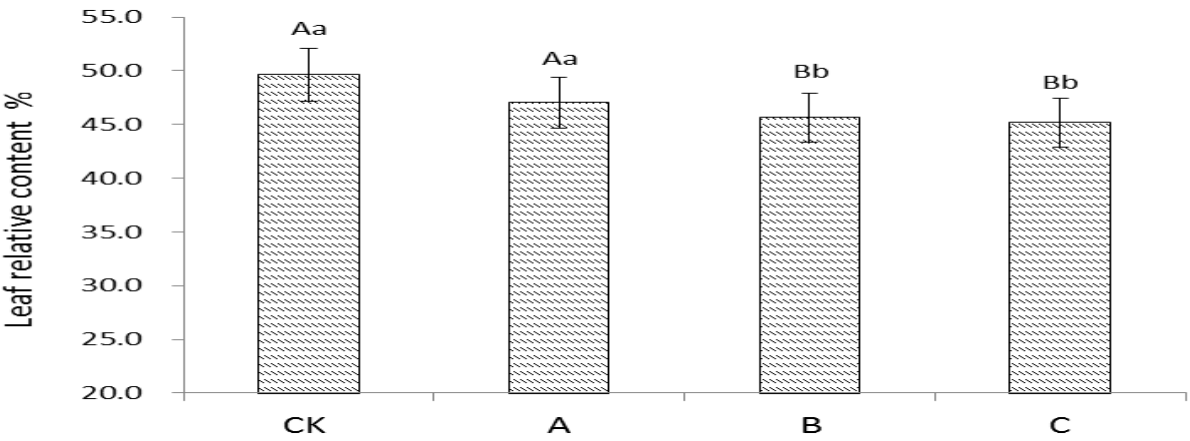

Fig.3 Effects of different soil water potential on relative water content of rice leaf

The effect of LAI

The leaf area of rice is the main organ of photosynthesis. The leaf area index (LAI) refers to the ratio of green leaf area to land area in a certain growth period, which is the main characteristic of the source. The suitable leaf area index is very important for the formation of yield. It is important to study the growth and decline of leaf area under different water treatments, which plays an important role in the cultivation of water-saving and high-yielding cultivation. The leaf area index of CK was decreased in the normal aquaculture stage, and the difference between CK and treatment A was not significant at the end of water treatment on September 5. The LAI trend of each treatment on September 10, September 15 and September 20 was basically the order of CK> A> B> C, the difference between CK and treatment A was not significant, and treatment A and treatment B, C between the significant difference.

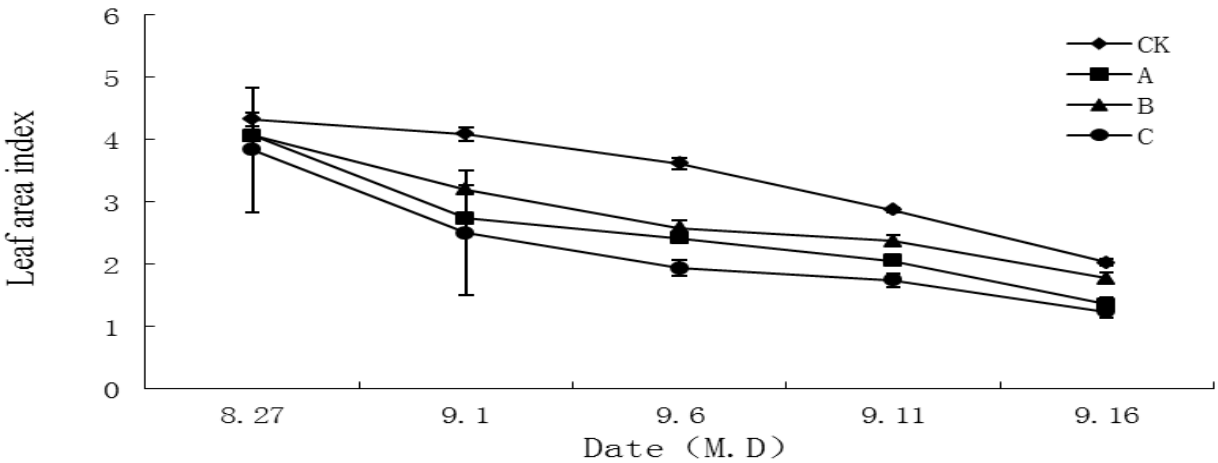

Fig.4 Effects of different soil water potential on leaf area index of rice

Conclusions

The results of the experiment in 2011 and 2012 showed that the yields of treatment A was higher than CK by 3.78%, which was 2.88% and 4.82% higher than that of treatment B and treatment C. The treatment of A (0kpa) water Which is beneficial to the growth and yield of rice. According to the results of former researchers[2,13-16], it is shown that -10 pka is the water control lower limit of rice growth period. When the water control potential is 0kpa, the number of rice grains per spike, 1000-grain weight and seed setting rate are the highest. Therefore, the yield of rice is also the highest. However, during the ripening stage, when the water potential was -15 kPa, the

proline content of rice leaves was the highest, because the proline was beneficial to the water holding capacity of the cells or tissues, and the water potential was lower than the water control lower limit of the rice growth period. When the water potential was -30 kPa, the content of proline decreased, indicating that there was a certain water limit in the production of leaf proline. Chlorophyll is beneficial to rice photosynthesis, and the chlorophyll content of rice leaves is the highest when the water potential is -30 kpa, but why the mechanism of lower water potential is not conducive to the formation of chlorophyll in rice leaves is further studied. The relative water content of rice leaves reached the maximum at CK and 0 kpa, indicating that keep the water in ripening stage was more favorable for rice growth. In the ripening stage, when the water potential is flooded and the aquifer is maintained, the LAI of rice is the largest and the slowest, and it is the main characteristic of "source", which plays a vital role in rice yield. The results showed that increasing the effective leaf area and high efficiency leaf area under the appropriate LAI condition was the comprehensive quality index of improving the "pool" and "source" coordination level, and also the quality index of the high light efficiency group. In this study, it was found that the water control potential of rice during ripening was both beneficial and negative at 0 kPa, especially for dry matter production, but its sheath quality was the highest, significantly higher than others. Spike and root quality is also high, but overall, the total dry matter accumulation of rice is the most. Production is the highest. The results showed that the control of different water potentials under salt and alkali stress caused the difference of physiological indexes of rice, and finally affected the yield. Therefore, it was better to control the water potential under the influence of soda salinity of the growth, and thus achieve high yield and quality of the role.

Acknowledgements

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