Effects of Different Soil Water Potential at Tillering 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 tillering 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 -30kPa (H3), and CK (continuously flooded), a comparative study of different soil water potential of tillering stage on grain yield, dry matter production, leaf physiological treats and growth dynamic was conducted. The results showed that the period of water stress, the leaf relative water content of the soda saline soil of rice had declined rapidly, and the falling range with the same level of water stress. The H1 had recovering the level of CK after 15days of rewatering. The tiller number from high to low showed a trend of CK＞H1＞H2＞H3 with the drop of water potential in saline-alkali soil, the date of top tillering was the same from CK to H1, but H2 and H3 had 5-10 days later than CK. Water stress could restricted the expansion of the rice leaf area and with the exacerbation of the water stress degree, the rice leaf area index decreased. The date ofH1,H2 and H3 come to maximum LAI were delayed 5days compared with CK. There had a significantly different among all treatments as to the dry matter accumulation, showed a trend of H1>CK>H2>H3, and the difference between H1,CK and H2,H3 had reached significant level（$P<0.05$）.The rice yield from high to low showed a trend of CK＞H1＞H2＞H3, compared with the CK, the H1\H2 and H3 decreased 11.45 % , 24.92% and60.24% respectively in the soda saline- alkali soil under moist irrigation at the tillering stage. So in soda saline-alkali soil continuously flooded irrigation is necessary.

Introduction

The Songnen Plain is the largest plain in northeast China and the second largest plain of China after the Huang-Huai-Hai Plain in central China. The west side of this plain, mainly the western portion of Jilin and Heilongjian Provinces, is one of the five largest salt affected soil regions in

China[1]. The area of salt affected soil, 0.5 to 1.0% total salts, encompasses 3.42×106 ha, which accounts for over 19.0% of the total area[1,2]. In order to effectively utilize these saline-sodic soils, rice (*Oriza sativa L.*) was planted in this plain because the flooded water not only is beneficial to its growth but also is necessary for leaching salts. In recent years, with the shortage of water resources, the contradiction between the development of rice and the limited water resources was sparked, so more and more people pay more attention to problem of the paddy field water saving. There had lots of reports about water-saving rice, regulation of irrigation and water and soil coupling et al. at present. The results showed that Irrigation water as long as mete the physiological water requirement and ecological water requirement, the higher yield could been gained and the more irrigation water was wasted[2-5]. The moderate drought stress could helped build suitable plant type structure, rise net photosynthetic rate and vigor of leaf[6-9]. The interval irrigation could to be benefit of good quality high yield. The research of effects of different degree water stress at different growth and development stage was the theoretical basis of water-saving irrigation for rice[1,10-14].For the sake of rice in different growing phases have different demand for water, the reaction of after suffer a certain degree of water stress was not the same, and in a certain growing stage showed a strong patience, while in some stage reaction was very sensitive[12-17]. So far the planting structure for water-saving on soda saline-alkali soil, especially investigation of plant growth dynamic and dry matter distribution mechanism at the tillering stage of rice were very little. We therefore conducted a study to determine how effective different water potential is at plant physiological characteristics, dry matter accumulation and yield of rice, discuss the soil moisture adaptability of rice tillering stage in these saline-sodic soils in the western part of Songnen Plain. These results could provide a scientific basis for sustainable development and water-saving drought-resistant cultivation in saline-sodic soils.

Materials and method

Materials and experimental site

This test was conducted at test base of Jilin Agricultural University in 2013-2014. The variety of changbai 9 with its main varieties of soda soline-alkali soil was used to studied. The average values of pH, salinity, organic content, available N, available P and available K for the selected soil were 8.52, 0.23%, 1.89%, 158.8mg/kg、32.64mg/kg and 153.6mg/kg respectively.

Experimental design

We used pot methods in the early stage of the rice tillering by manual control water processing.We measured leaf physiological traits, dry matter production and yield under soil water potentials of 0 Kpa(H1), -15 Kpa(H2), -30Kpa(H3) and CK(continuously flooded).

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% K_2O 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. Four seedings per hill , four hills per pot were transplanted into each pot. Water treatment was conducted on June 10, and rewatering on June 25, a total 15days water controlled in two years for the sake of reproductive process of two years were consistently. Rainproof with opened on sunny days, clouded on rainy days or at evening, was installed during test to prevented natural precipitation that guaranteed other ecological factors close to the natural environment under condition of artificial controlled water.

Sampled and measured

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

Tiller number and LAI. Since June 10, we was measured the tiller number of 3 plot each treatment for every 5 days and measure all green leaf length (midrib long) and width (maximum width) . LAI=[Long(cm) ×width(cm)×0.75] / area(land)

Dry matter. All the plants of two pots were picked for measure dry mater on june 24(the day of over water treatment), July 10(15 days after rewatering), July 25(jointing-booting stage), August 10(heading stage), August 25(filling stage) and September 10(dough stage). The ground part of plant was separated by stem and 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.

Yield. The mature crop was harvested by cutting it at soil level. After sun-drying, the heads were counted and separated from the straw to record the number of heads and the weight of straw. Threshing was done by hand and grain number was recorded. Data was calculated panicle number, grains per panicle, 1000-grain weight , seed setting percentage and Yield.

Statistical data analysis

All data obtained were the average of three replicas. Statistical analysis on one-way variance analysis (ANOVA) was performed using SPSS 17.0. When significance at a 0.05 level was indicated, means were separated by a Least Significant Difference (LSD) Procedure.

Result and discussion

Leaf relative water content

The Leaf relative water content of rice growth in soda saline-alkali soils declined rapidly during water stress(Fig.1), and the falling range consistent with the degree of stress. RWC of H1 suffered water stress after 15days was 7.78%, which lower than that of CK. When rewatering 15 days, the RWC could recovered to the level of CK. The RWC of H2 and H3 were lower than CK by 12.29% and 14.42%, respectively, and could rapidly been promoted, there could to flat the level of CK at heading stage. Above results indicated that there had correlation between leaf relative water content of rice and water potential in soda saline-alkali soils.

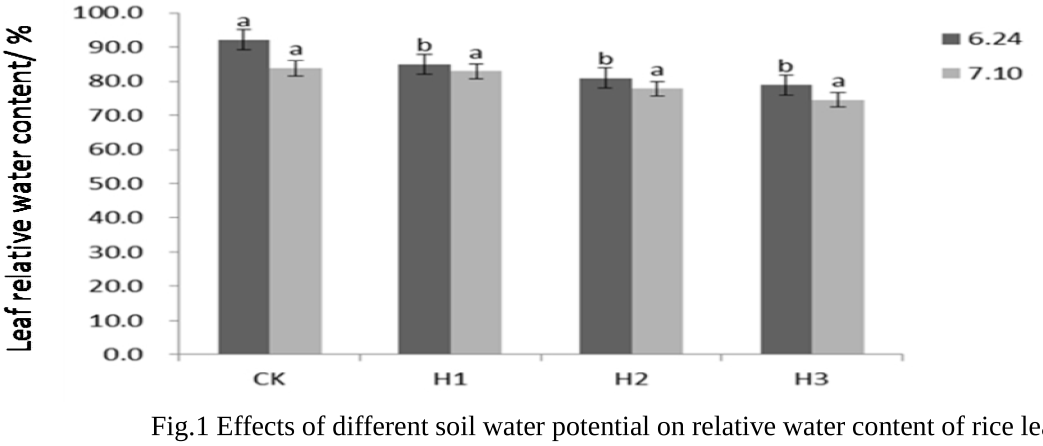

Fig.1 Effects of different soil water potential on relative water content of rice leaves

Dynamics of tiller number

Different water controlled treatment of rice on soda saline-alkali soils, has had greater effects on tiller number. After water stress treatment, the tiller number of CK with 20.45 was the highest H1 was18.22, H2 was17.01 and H3 had the least tiller number with only 14.64.The same date of top tillering stage between CK and H1, which on July 15, had achieved the maximum tiller number. The tiller could been growth rapidly after rewatering, and the date of maximum tiller number were later 5 to10days than CK. With the development of rice, the tillers of growth later, had most become invalid tillers for light, nutrition and other reasons and the valid tiller rate was at a lower level eventually. From the tiller dynamic curve we known that the inhibitory effect of mild water stress on rice tillering stage in soda saline-alkali soils is not obvious, but could been effectively decreased the invalid tillers, while severe water stress could significantly inhibit the occurrence of rice tillers, and ultimately affect the effective panicle number of rice.

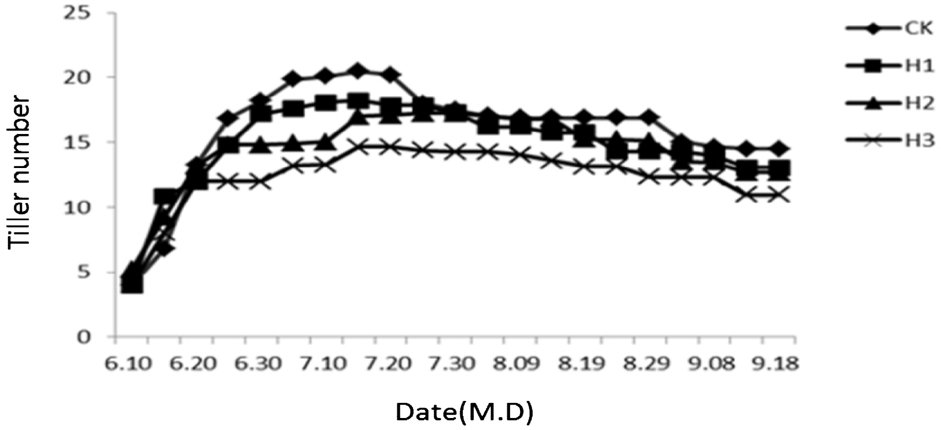

Fig.2 Effects of different soil water potential on tillering dynamics of rice

LAI of rice

Leaf area was the basis of photosynthesis and the main characteristics of the source, appropriate leaf area index was very important to yield formation. From the fig.3 showed that water stress at tillering stage would restricted the expansion of the rice leaf area, with the aggravation of the water stress level, leaf area index had decreased. The LAI showed a trend of CK>H1>H2>H3, with from the largest to least were 5.45,5.30,4.36 and 4.24 respectively. The maximum of CK's LAI was appeared in the August 4, while the H2 and H3 delayed 5 days than CK. The different between CK and H1 were not significant, but H2 and H3 LAI had reduced obviously. Above results indicated that water stress in tillering stage on soda saline-alkali soils, were not only affected the duration time of LAI, but impacted the growth situation of leaf.

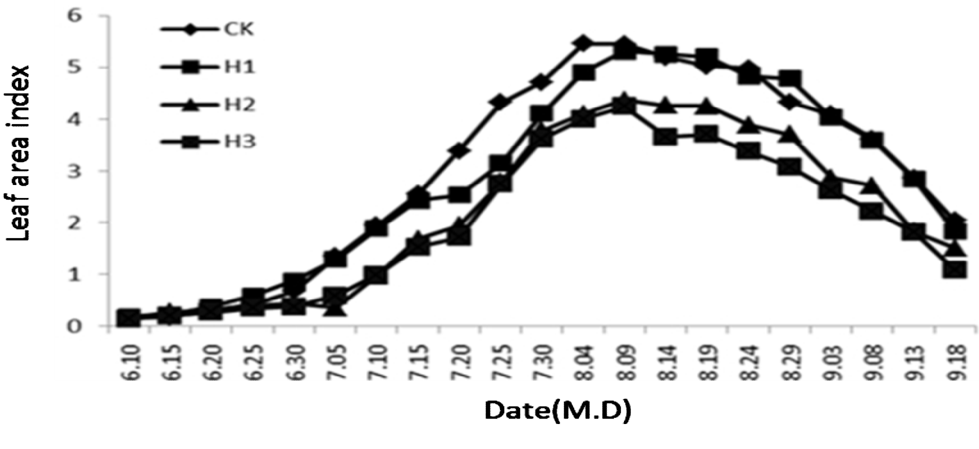

Fig.3 Effects of different soil water potential on leaf area index of rice

Dry matter content

The dry matter of different part of rice under different soil water potential in soda saline-alkali soil showed a certain difference(Tab. 1). The plant growing of all the treats was consistent basically, dry matter had no significantly different after the end of treatment(June 24). After 15 days of rewatering, the total dry matter weight difference had become obviously, showed a trend of H1>CK>H2>H3, the difference between H1,CK and H2,H3 had achieved the level of significance($P<0.05$) and compared with H2, H3, H1 and CK were higher than 54.48%, 93.82% and 54.48%, 93.82% respectively. Total dry matter weight of all treatments showed a trend of CK>H1>H2>H3 at heading stage(July 25) and dough stage(September 10), the difference had achieved significance level ($P<0.05$). Total dry matter weight of all treatments showed a trend of H1>CK>H2>H3 at full heading stage(August 10) and Filling stage(August 25).

Further analysis table 1, we found that root dry matter weight showed wet condition is significantly higher than other treats, assumed H1>CK>H2>H3. These indicated that in soda saline-alkali soils, kept the soil been in moist state was conducive to the growth of root and promoted to penetrate of roots of rice in tillering stage. With further decrease of soil water potential, under the effects of water stress and saline threat, rice root system had significantly affected and thereby affected the dry matter accumulation of the whole plant.

Table 1. Effects of different soil water potential on dry matter weight of rice

Date	Part	CK	H1	H2	H3
6.24	Leaf g / hill	1.15	1.16	1.14	1.16
	Leaf sheath g / hill	1.28	1.35	1.25	1.33
	Root g / hill	0.66	0.66	0.63	0.67
	Total dry matter g / hill	3.09 a	3.17 a	3.02 a	3.16 a
7.10	Leaf g / hill	4.73	4.32	3.14	2.37
	Leaf sheath g / hill	7.25	6.81	3.74	3.16
	Root g / hill	4.28	5.17	3.65	2.88
	Total dry matter g / hill	16.26 a	16.30 a	10.53 b	8.41 c
7.25	Stem g / hill	1.75	1.41	1.17	0.96
	Leaf g / hill	8.54	6.67	6.14	5.04
	Leaf sheath g / hill	14.24	10.1	9.42	7.61
	Root g / hill	5.17	5.73	4.54	3.90
	Total dry matter g / hill	29.70 a	23.91 b	21.27 bc	17.51 c
8.10	Stem g / hill	13.21	13.05	10.52	8.74
	Leaf g / hill	9.64	9.97	8.62	7.86
	Leaf sheath g / hill	14.11	15.07	8.90	7.22
	Panicle g / hill	5.45	5.27	4.76	4.28
	Root g / hill	6.43	7.49	5.65	5.16
	Total dry matter g / hill	48.84 a	50.85 a	38.45 b	33.26 c
8.25	Stem g / hill	19.80	21.17	16.55	14.28
	Leaf g / hill	9.85	9.73	6.68	5.77
	Leaf sheath g / hill	14.53	14.8	11.00	10.09
	Panicle g / hill	15.23	14.4	12.46	11.42
	Root g / hill	4.94	5.27	4.25	3.14
	Total dry matter g / hill	64.35 a	65.37 a	50.94 b	44.70 b
9.10	Stem g / hill	11.20	10.78	9.44	6.84
	Leaf g / hill	7.65	7.31	6.20	4.21
	Leaf sheath g / hill	11.54	10.37	8.62	6.47
	Panicle g / hill	29.94	27.16	22.62	16.34
	Root g / hill	4.71	4.89	4.10	3.12
	Total dry matter g / hill	65.04 a	60.51ab	50.98 b	36.98 c

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

Yield traits and yield

From the influence of different water treatment on rice yield (table 2), water stress at tillering stage had seriously restricted the normal growth of tillers of rice in soda saline-alkali soils. The panicle number of CK was more than other treats, although CK had some invalid tillers to death in later stage of tillering and had reached the significantly level ($P < 0.05$). The grains per panicle and Seed setting percentage of CK were also higher than other treats, but there had no significant difference. We found that yield showed a trend of decreasing along with the water stress degree, characterized by CK>H1>H2>H3, and had reached the significantly level ($P < 0.05$). H1, H2 and H3 respectively 11.45%, 24.92% and 60.24% lower than the CK.

The above description indicted that the moisture deficiency conducted at tillering stage in soda saline-alkali soil, could inhibit the occurrence of rice tillers, and reduced the number of valid panicles per unit area, and was the main reason of significant reduction in the yield of rice.

Table 2. Effects of different soil water potential on yield and yield traits of rice

Treats	Year	Panicle number/ per pot	Grains per panicle	1000-grain weight /g	Seed setting percentage /%	Yield/ per pot·g
CK	2013	58.26	83.12	25.01	81.15	101.02
	2014	56.14	79.14	25.67	81.34	99.69
	Average	57.20a	81.13a	25.34a	81.25a	100.36a
H1	2013	50.04	83.07	25.42	80.19	91.84
	2014	53.58	79.13	25.98	81.99	89.16
	Average	51.81b	81.10a	25.70 a	81.04a	90.05b
H2	2013	49.17	79.03	25.11	79.24	80.03
	2014	48.85	77.97	25.33	77.32	80.65
	Average	49.01b	78.50a	25.22 a	78.28a	80.34c
H3	2013	40.02	79.87	26.03	81.22	64.13
	2014	41.84	80.19	25.05	79.00	61.13
	Average	40.93c	80.03a	25.54 a	80.11a	62.63d

Data followed by common capital letters and lowercase letters within a column are not significantly different at the 0.01and 0.05 probability levels, respectively.

Conclusions

Water treats of rice on soda saline-alkali soils, had greater effects on tiller number, and the valid tiller rate was at a lower level eventually. The expansion of the rice leaf area could been restricted by the changed of water potential at tillering stage, and with the aggravation of the water stress level, leaf area index had decreased. The maximum LAI of H2 (-15 Kpa) and H3(-30 Kpa) were appeared delayed 5 days than CK (continuously flooded). The plant growing of all the treats was consistent basically, dry matter had no significantly different after the end of treatment. We found that kept the soda saline-alkali soils been in moist state could conducive to the growth of root and promoted to penetrate of roots in tillering stage. Water stress had greater effect on tillers of H2 (-15 Kpa) and H3(-30 Kpa), the main reason was that the stress level was so larger by water stress associated saline stress intensity. So the number of tiller and plant growth were restrained, which result was lack of effective panicles per unit area and more to serious influenced the yield. In state of H1 (0 kPa), water stress was lighter than H2 and H3, but the yield was still lower than CK ultimately. Rice tillering stage of soda saline-alkali should maintain appropriate water layer, it can meet the required for normal growth and development of rice, and to guaranteed high yield.

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