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Original Research

How Different Nitrogen Application Rates Affect Yield Composition and Nitrogen Uptake of Rice (*Oryza sativa* L.) in a Saline-Sodic Paddy Field

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Abstract

Planting rice (*Oryzasativa*L.) is an effective and feasible approach for improving salt-affected soils, especially in saline-sodic soils. Improved rice is the main biological measure for rapid treatment and utilization of a saline-sodic paddy field. Reasonable application of nitrogen fertilizer is an important measure for obtaining saline-sodic soil high yield. Dongdao 4 (D-4), Dongdao 2 (D-2), Changbai 9 (C-9), and Baijing 1 (B-1)) were studied by a field experiment in this paper. On the growth, yield, and yield component responses of different nitrogen levels (150 kg N/ha, 225 kg N/ha and 300 kg N/ha), and the nitrogen uptake of four saline-tolerant rice cultivars at different nitrogen application levels was calculated, which provided a useful reference for the rational application of nitrogen fertilizer in a saline-sodic paddy field. The results showed that: biomass of four kinds of rice accumulates over time and reached their maximums in September, with the biomasses of D-2 and D-4 reaching the maximum of 225 kg N/ha, and C-9 and B-1 reaching the maximum at 300 kg N/ha, which is related to rice varieties; the yields of four salt-tolerant rice plants reached the highest in 150 kg N/ha; applied nitrogen fertilizer reasonably was beneficial to increase the number of spikes and the number of effective grains per spike, in this experiment, the optimum amount of nitrogen is 150 kg N/ha, and the number of spikes and the number of effective grains per spike also were major factors in increasing production. With 1000-grain weight, primary and secondary branches made no significant contribution to the yield; the N uptake of four kinds of rice gradually increased over time and reached the maximum in September. There was no significant difference in the nitrogen grain production efficiency of 4 rice varieties under different nitrogen application rates; with the increase of nitrogen application rate, partial productivity of nitrogen fertilizer

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nitrogen of 4 rice varieties all decreased. Therefore, reasonable application of nitrogen fertilizer promoted the uptake and transfer of nitrogen to the plant.

Keywords: **s**aline-sodic paddy field, nitrogen uptake, yield composition, nitrogen grain production efficiency, partial productivity of nitrogen fertilizer

Introduction

Salt-affected soils, including saline soils and saline-sodic soils, are widely distributed across more than 100 countries covering regions all over the world except for Antarctica [1-2]. It is estimated that globally more than 800 × 10^6 hectares of land is suffering from salinization and alkalization [3], which is a major impediment to world crop production [4-7]. The total area of saline-sodic soils in northeastern China has reached 3.42 million ha [8-9], mainly in the western portion of Jilin and Heilongjiang provinces, with soil pH ranging from 7.02 to 10.16 [10]. Saline-sodic soil is widely distributed in the western Songnen Plain of northeastern China, and the total area of saline-sodic soil is about 337 × 10^4 hectares. More alarmingly, approximately 20.0 × 10^3 ha of land is newly salinized and/or alkalized every year in this area, posing a serious threat to crop production [11-14]. Sodium carbonate and sodium bicarbonate (Na_2CO_3 and $NaHCO_3$) are two main salts in saline-sodic soil, with soil pH mostly reaching 8.5 or more, and soil physical properties are very poor [15]. In the long-term practice of production, we found that rice is one of the few crops that can thrive on salt-affected soils because rice can improve its tolerance to salt and alkali stress through its own and outside osmotic adjustment, inorganic ion regulation, or nutrient regulation. In saline alkali stress, rice seedlings can synthesize water-soluble and strong soluble solutes in cells by their own osmotic adjustment ability to protect the protein, protein complex, and cell membrane structure in cells from damage. Therefore, for the cells' normal physiological activity an entry crop for desalinization of salt affected lands is recommended [16-17]. Planting rice (*Oryza sativa* L.) is a successful example of the biological improvement of saline-sodic soils [5, 10]. Rice is one of the most important food crops in the world.

Rice has provided the food supply for more than 3 billion people in the world (AR IRRI – Global Rice Science Partnership (GRiSP), 2010). But its current rate of yield increase of 1.0% is less than the 2.4% per year that is required to double its production by 2050 [18]. China is one of the largest countries for rice production and consumption, with the second largest rice plantings and the highest rice yield in the world [8]. Rice is cultivated in a quarter of the arable land in China and supports more than half of its population [19]. Therefore, improving rice productivity is crucial for food security, economic development, and sustainable agriculture. Rice is considered to be quite sensitive to salinity [20-22], but only moderately tolerant of sodicity [3, 23]. Practice has shown that planting rice is an effective way to control, improve, and utilize soda saline soil [24]. In the history of the breeding and cultivation of salt-tolerant rice varieties, the rice that was planted in saline-sodic, has long dominated the cultivation of single cultivars and lacks the complementary advantages of many varieties. For example of C-9, from 1994 it was promoted planting for up to 20 years, in the saline-sodic rice cultivation area once more than 60%, the species lodging resistance is poor and the yield is reduced, but there is a lack of alternative varieties [25]. Therefore, it is necessary to use molecular breeding and other high-tech rapid orientation of cultivating new varieties of saline-tolerant rice. In 2007 the western province of saline-sodic large-scale development of rice projects started in Jilin Province, which plans to cultivate salinized rice fields 27 million hm^2, and annual output of rice of 1.65 million kg [15]. The new varieties of tolerance to saline-sodic and high-yield and high-quality rice, which are represented by Dongdao 4, Dongdao 2, and Baijing 1, are widely recognized and planted in large area [15]. Although rice can coordinate its own acid-base balance, it is more affected by soil nutrients.

Nitrogen is one of the most important plant nutrients in arable agriculture. Nitrogen application rate is an important factor affecting the nitrogen use efficiency of rice. Nitrogen consumption consumed by rice production in China accounts for 37% of the total nitrogen fertilizer consumption in the world [26]. Chinese rice production in the application of high nitrogen fertilizer and low utilization rate of the problem is particularly prominent, Chinese single-season average nitrogen fertilizer for 180 kg/ha, higher than the world average of about 75%. The application rate of nitrogen fertilizer in rice is up to 300-450 kg/ha, while the utilization rate of nitrogen fertilizer in paddy field is only 30~35% [27]. The application of nitrogen (N) fertilizer is the primary means of increasing rice production and addressing the problem of population growth and food supply [28-30]. However, fertilizer N use efficiency (NUE) decreases with increasing N fertilizer inputs, which has harmful repercussions such as surplus soil N, nitrate leaching, mineral N runoff, and agricultural greenhouse gas emissions that lead to eco-environmental problems, including acid rain, soil acidification, and water eutrophication [31-33]. NUE is also positively related to the soil carbon budget [34]. Nitrogen (N) fertilization affects the SR dynamics of agro ecosystem and its relationship with abiotic factors [35]. The effects of different fertilizer sources affect soil metabolism and soil carbon balance [36-38]. It has been determined that in autumn hay crops, the nitrogen fertilizer application in late winter increases the balance of soil carbon, which is also due to the increase in crop productivity. The changes of SR and Rh induced by different fertilization methods are closely related to the C input of fertilizer. Fertilizer application alone provides a higher soil C input, but this is the least efficient method for CO_2 emission reduction [34]. High external N input and ineffective fertilization practices have led to low nitrogen use efficiency [39]. As nitrogen use efficiency has been low, the utilization efficiency of nitrogen fertilizer in a saline-sodic paddy field is only 20~25% [40], which is significantly lower than that of common paddy field (30~35% of nitrogen use efficiency NUE) [41]. A large number of studies have shown that salinity reduces the accumulation of nitrogen in plants [42]. Nitrogen application not only promotes crop growth but also increases salt tolerance, the rational application of nitrogen fertilizer is a prerequisite for the normal growth and development of rice, but also an important guarantee for high yield of rice in saline-sodic soil [5]. Therefore, the optimal management of nitrogen, on the basis of ensuring the continuous improvement of grain production, increasing the efficiency of nitrogen use, and reducing the amount of nitrogen fertilizer in saline-sodic paddy field will be a primary problem in agricultural production and research [43].

The objectives of the current study were: (1) to verify the changes of yield and yield components of four salt-tolerant rice plants under different nitrogen application levels and (2) to verify the nitrogen uptake characteristics of four salinity-tolerant rice varieties under different nitrogen application levels.

Materials and Methods

Experimental Site

The experiment was carried out from April to October 2015 at Da'an sodic ecology experiment station (45°35'58"-45°36'28"N, 123°50'27"-123°51'31"E) located in the middle of the Songnen Plain. The climate was semi-arid and temperate, and the annual average temperature is 4.3ºC, the annual average rainfall is 410 mm, of which about 56% of the precipitation occurred in July and August, the annual frost-free duration is 137 days. The soil type is saline-sodic meadow soil and its main soluble cation are Na^+ and K^+, and the main soluble anions are HCO_3^- with lesser mounts of CO_3^{2-} with a soil pH usually above 8.5.

Rice Varieties

Four rice varieties of tolerant salinity were selected in this experiment: No. 4 of Dongdao rice (D-4), No. 2 of Dongdao rice (D-2), No. 9 of Changbai rice (C-9), and No. 1 of Jijing rice (B-1).

D-4 is a new variety cultivated by the Northeast Institute of Geography and Agroecology, Chinese Academy of Agricultural Sciences, and the growth period is 131 days. In 2010 it was approved by Jilin Province. It has the advantage of a sturdy stalk, lodging resistance, functional leaf lifting, strong vitality, early earning, long filling time, full-grain filling, and rarely ineffective tiller. Single from the yield and other traits can be a large area of cultivation and promotion [7].

D-2 is a new variety cultivated by the Northeast Institute of Geography and Agroecology, Chinese Academy of Agricultural Sciences Growth. It is a ripe variety with a period of 136 days or so, and artificial inoculation and remote field identification, resistance to sheath blight, and resistance to blast, plague, and spike [44]

B-1 is cultivated by the Baicheng Academy of Agricultural Sciences. It is disease resistant and has salt tolerance of the better variety of rattan 138 for the male parent for sexual hybridization, hybrid offspring through the greenhouse or Hainan generation, and by genealogy breeding. It is a medium early-maturing variety with a growth period of 131 days. The stem is tough and lodging resistant, it has strong tillering ability, it is compact and has salt alkali resistance and low temperature resistance, plus strong stress resistance [45].

C-9 is cultivated by the Rice Research Institute of Jilin Academy of Agricultural Sciences, as early as 1994 through the Jilin Province crop varieties validation. The varieties are of high yield, stable production, saline-sodic tolerance, and other characteristics. Early maturing varieties have a growth period of about 130 days. Rice blast resistance and resistance to sheath blight are all stronger, and it is resistant to fertilizer without lodging [46].

Experimental Design

In this study, we studied the growth, nitrogen accumulation, and yield changes of four main saline-sodic tolerant rice cultivars under three nitrogen application rates. The treatments of three nitrogen treatments included local conventional dosage (300 kg N/ha), recommended amount (medium nitrogen 225 kg N/ha), and reduction (low nitrogen 150 kg N/ha). Four main salt-tolerant rice varieties were D-4 (grow seedlings on April 18), D-2 (grow seedling son April 19), B-1 (grow seedling son April 12), and C-9 (grow seedling son April 19), respectively. Experimental selection: West 20 (cement pool) W7, E6, and E8.

Specific design: According to the order of C-9, D-4, B-1, and D-2, and transplanted on May 24 to May 25, each line was inserted in 20 rows. Base fertilizer is 18-18-18 Sa Kefu compound fertilizer 2.68 kg/ha; the amount of pure nitrogen fertilizer, phosphate fertilizer and potassium fertilizer were 72 kg/ha. The application of nitrogen fertilizer was divided into 3 treatments: low, middle, and high. Among them, the nitrogen level of 225 kg/ha is for the local habits, low nitrogen reduced 1/3, high nitrogen increased 1/3, respectively, low nitrogen was 150 kg/ha treatment, topdressing 34 Jin urea; middle nitrogen was 225 kg/ha treatment, topdressing 67 kg urea; and high nitrogen was 300 kg/ha treatment, topdressing 99 kg urea.

Topdressing nitrogen fertilizer method: In the E6 pool, in turn green, tillering term topdressing fertilizer 5 kg of urea, in tillering mid-term topdressing 7 kg of urea, before the spike, topdressing 5 kg of urea; in the E8 pool, in turn green, tillering term topdressing fertilizer 10 kg of urea, in tillering mid-term topdressing 13.5 kg of urea, before the spike, topdressing 10 kg of urea; in the W7 pool, in turn green, tillering term topdressing fertilizer 15 kg of urea, in tillering mid-term topdressing 19.5 kg of urea, before the spike, topdressing 15 kg of urea.

Determining Projects and Methods

Samples were taken for investigation 7 days after transplanting. Each time, the nitrogen fertilizer was taken for 7 days, samples were taken for investigating plant height of 30 rice plants (10 strains and 3 repeats) was tested, 30 rice tillers (10 plants, 3 replicates) were tested, samples were taken as 3 replicates, and the fresh weight and dry weight of the 3 samples were tested, the dry sample powder was broken to measure total nitrogen content, and samples are taken for measuring yield during harvest. Determining yield structure: the number of spikes, effective grain number per panicle, 1000-grain weight, primary branch and secondary branch ratio. Soil nitrogen content was determined by the Kjeldahl method. The contents of root, stem, leaf, sheath, and spike were measured by 105ºC, 80ºC drying to constant weight weighing method.

The whole plant N uptake = Root N uptake + Stem N uptake + Leaf N uptake

Partial factor productivity of applied nitrogen (PFP, kg/kg) = Grain yield in fertilization area / Amount of nitrogen applied

Nitrogen grain production efficiency (g grain/g N) = Rice production/ The total nitrogen content of plant.

Data Processing

Data analyses were carried out using SPSS 21.0 statistics package (SPSS, Chicago, IL, USA). The ANOVA and Duncan methods were used to compare the different data. Drawn with origin 9.1 software and Excel.

Results and Analysis

Biomass Changes

The aboveground biomass of 4 rice varieties under 3 nitrogen application rates were shown as Fig 1.

Under different nitrogen application rates, the biomass (aboveground dry weight) accumulated over time. Four varieties of rice under different nitrogen rates, the biomass showed a rapid growth stage after July 15 until September 15. For example, on September, in 225 kgN/ha, the biomass of D-4 was 2.3% higher than that in 300 kgN/ha, and 5.2% higher than that in

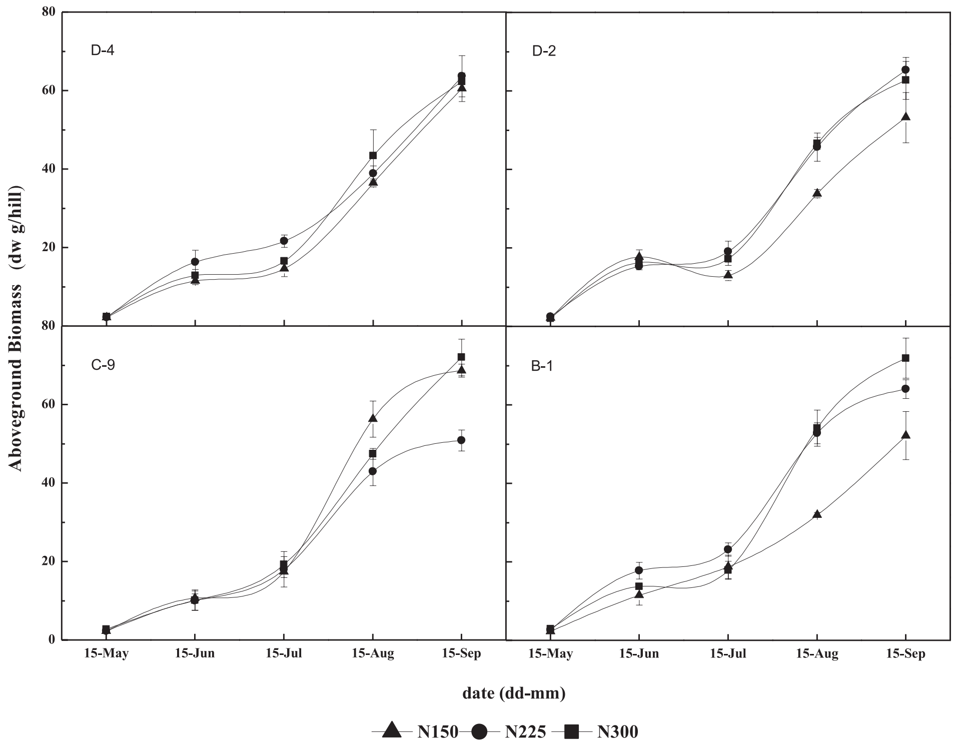

Fig. 1. Changes in biomass of salt-tolerant rice main varieties under three nitrogen levels.

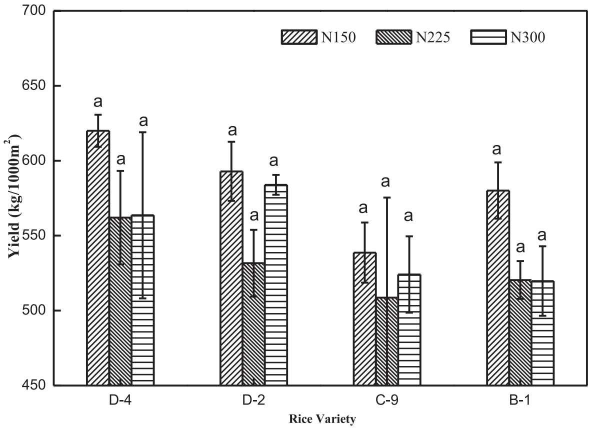

Fig. 2. Rice under different nitrogen levels and the output of each type.

150 kg N/ha; in 225 kgN/ha, the biomass of D-2 was 4.1% higher than that in 300 kg N/ha, and 22.7% higher than that in 150 kg N/ha; in 300 kg N/ha the biomass of C-9 was 41.5% higher than that in 225 kg N/ha, and 5.0% higher than that in 150 kg N/ha; in 300 kg N/ha the biomass of B-1 was 33.1% higher than that in 225 kg N/ha, and 37.8% higher than that in 150 kg N/ha.

Change in Production

The yields of 4 rice varieties under 3 nitrogen application rates are shown in Fig. 2.

The results showed that there was no significant difference between the yield of four kinds of salt-tolerant rice under the different nitrogen application rates, but it can be seen from the figure that the four kinds of rice had the highest yield in 150 kg N/ha treatment.

In 150 kg N/ha, the yield of D-4 was 10.0% higher than that in 300 kg N/ha, and 10.3% higher than that in 225 kg N/ha. The yield of D-2 was 1.5% higher than that in 300 kg N/ha, and 11.5% higher than that in 225 kg N/ha. In 150 kg N/ha, the yield of C-9 was 2.8% higher than that in 300 kg N/ha, and 6.0% higher than that in 225 kg N/ha. In 150 kg N/ha, the yield of B-1 was 11.6% higher than that in 300 kg N/ha, and 11.5% higher than that in 225 kg N/ha. The results showed that in 300 kg N/ha, the yield of rice from high to low was D-2> D-4> C-9> B-1. In 225 kg N/ha, the yield of rice from high to low was D-4> D-2> B-1> C-9. In 150 kg N/ha, the yield of rice from high to low was D-4> D-2> B-1> C-9 in150 kg N/ha.

Analysis of Yield Components

The number of spikes of four kinds of rice decreased with the increase of nitrogen application and reached the maximum in 150 kg N/ha. B-1 had the highest number of spikes in four kinds of rice in 150 kg N/ha, and there was no significant difference between D-2. B-1 also had the highest number of spike in four kinds of rice in 225 kg N/ha, D-2 had the highest number of spike in four kinds of rice in 300 kg N/ha. In general, the number of effective grains per spike of four varieties of rice decreases with the increase of nitrogen application rate, and reached the maximum in 150 kg N/ha, except for D-2, which had the highest the number of effective grains per spike in 225 kg N/ha. D-4 had the highest the number of effective grains per spike in 150 kg N/ha, and there was no significant difference between others. D-4 also had the highest the number of effective grains per spike in 225 kg N/ha and in 300 kg N/ha. There was no significant difference between the number of effective

Table 1. Yield components of different varieties of rice.

Rice varieties	Amount of nitrogen applied (kg/ha)	Number of spikes (spike/hill)	Effective number of grains per spike (grain No./hill)	1000 grain weight (g/1000-grain)	Primary branch / Secondary branches
D-4	150	16.5±0.58^{A}	1358.3±266^{A}	22.48±0.68^{B}	0.75^{B}
	225	15.5±2.64^{AB}	1175.3±250^{A}	22.59±0.14^{B}	1.12^{A}
	300	13.8±0.96^{B}	824.0±54^{B}	24.31±0.70^{A}	1.01^{AB}
D-2	150	18.8±2.99^{A}	1077.5±475^{A}	22.07±0.76^{B}	0.595^{B}
	225	15.0±1.41^{B}	1166.8±152^{A}	23.15±0.72^{A}	0.61^{A}
	300	14.8±1.26^{B}	760.0±101^{A}	23.52±0.23^{A}	0.69^{A}
C-9	150	15.3±2.06^{A}	919.5±147^{A}	22.67±0.26^{B}	0.63^{B}
	225	14.8±1.71^{A}	817.0±195^{A}	23.26±0.91^{AB}	0.95^{A}
	300	14.3±0.50^{A}	807.3±111^{A}	24.23±0.97^{A}	0.70^{B}
B-1	150	19.0±2.16^{A}	1024.3±149^{A}	21.20±0.72^{A}	0.74^{B}
	225	15.8±1.71^{B}	983.5±150^{AB}	21.77±1.04^{A}	0.87^{A}
	300	12.5±1.29^{C}	770.0±133^{B}	21.63±1.59^{A}	0.62^{B}

Note: The values in the table are the mean ± standard deviation (n = 4). There was no significant difference between the same rice varieties at the different nitrogen levels with the same capital letters ($P < 0.05$).

Table 2. Yield Components of rice under different nitrogen applications.

Amount of nitrogen applied (kg/ha)	Rice varieties	Number of spikes (spike/hill)	Effective number of grains per spike (grain No./hill)	1000 grain weight (g/1000-grain)	primary branch / Secondary branches
150	D-4	16.5±0.58[ab]	1358.3±266[a]	22.48±0.68[a]	0.75[a]
	D-2	18.8±2.99[a]	1077.5±475[a]	22.07±0.76[ab]	0.595[a]
	C-9	15.3±2.06[b]	919.5±147[a]	22.67±0.26 [a]	0.63[a]
	B-1	19.0±2.16[a]	1024.3±149[a]	21.20±0.72[b]	0.74[a]
225	D-4	15.5±2.64[a]	1175.3±250[a]	22.59±0.14[ab]	1.12[a]
	D-2	15.0±1.41[a]	1166.8±152[a]	23.15±0.72[ab]	0.61[b]
	C-9	14.8±1.71[a]	817.0±195[b]	23.26±0.91[a]	0.95[ab]
	B-1	15.8±1.71[a]	983.5±150[ab]	21.77±1.04[b]	0.87[b]
300	D-4	13.8±0.96[ab]	824.0±54[a]	24.31±0.70[a]	1.01[a]
	D-2	14.8±1.26[a]	760.0±101[a]	23.52±0.23[a]	0.69[ab]
	C-9	14.3±0.50[a]	807.3±111[a]	24.23±0.97[a]	0.70[ab]
	B-1	12.5±1.29[b]	770.0±133[a]	21.63±1.59[a]	0.62[b]

Note: The values in the table are the mean ± standard deviation (n = 4) There was no significant difference in the values of the same lowercase letters between the different rice varieties at the same nitrogen level ($P < 0.05$).

grains per spike of four kinds of rice in 300 kg N/ha . The 1000-grain weight of four kinds of rice increased with the increase of nitrogen application rate, and D-4, D-2, and C-9 increased significantly. The 1000-grain weight of B-1 was not significantly different under the three treatments.

Overall, the ratio of primary and secondary branches of D-4 was larger than the other three kinds of rice under the three nitrogen rates. With the increase of nitrogen application rate, the ratio of primary and secondary branches of rice showed an upward trend under the same variety. D-4, C-9, and B-1 reached the maximum in 225 kg N/ha.

Changes in Nitrogen Uptake

The nitrogen uptake of 4 rice varieties under 3 nitrogen application rates are shown in Fig. 3.

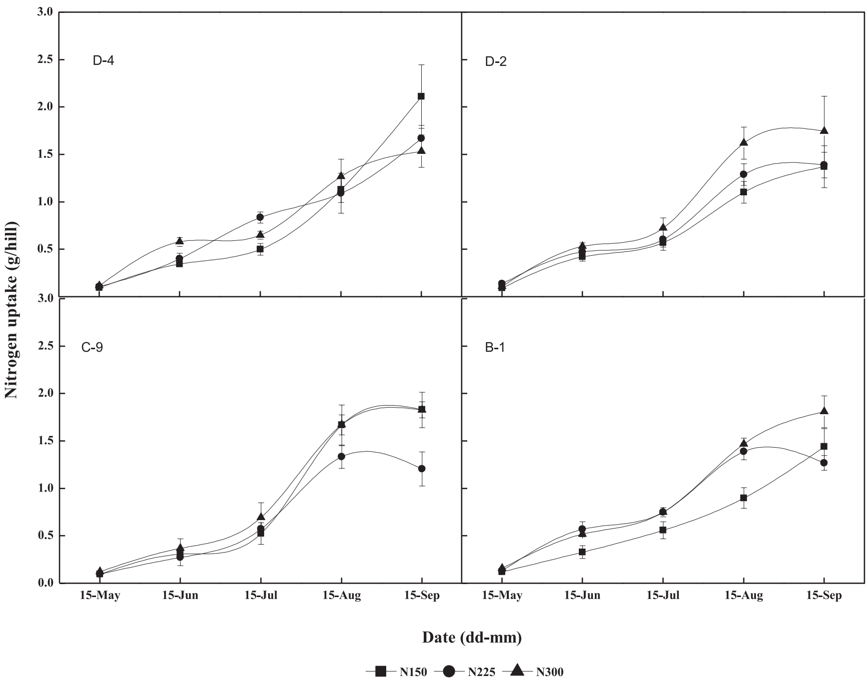

Fig. 3. Different development stages of the different rice varieties aboveground plant nitrogen uptake.

The nitrogen uptake of different rice in the three kinds of nitrogen applications is on the rise to a certain extent, and then declines. The N uptake of C-9 and B-1 reached the highest on August 15 in 225 kg N/ha. The N uptake of C-9 and B-1 reached a maximum on September 15, in 300 kg N/ha and 150 kg N/ha. The N uptake of D-4 and D-2 reached the maximum on September 15, under the three kinds of nitrogen application. In September, the N uptake of D-4 was highest in 150 kg N/ha, which was 37.0% higher than that in 300 kg N/ha, and 26.3% higher than that in 225 kg N/ha. N uptake of D-2 was highest in 300 kg N/ha, which was 25.9% higher than that in 225 kg N/ha, and 27.7% higher than that in150 kg N/ha. The N uptake of C-9 was the same in 150 kg N/ha and 300 kg N/ha, which was 52.5% higher than that in 225 kg N/ha. N uptake of B-1 was highest in 300 kg N/ha, which was 42.5% higher than that in 225 kg N/ha, and 25.7% higher than that in 150 kg N/ha. In September, the N uptake from high to low of four salinities tolerant rice was under 150 kg N/ha treatment: D-4> C-9> B-1> D-2; under 225 kg N/ha treatment: D-4> D-2> B-1> C-9; and under 300 kg N/ha treatment: C-9> B-1> D-2> D-2.

Changes in Nitrogen Grain Production Efficiency

The nitrogen grain production efficiency of 4 rice varieties under 3 nitrogen application rates are shown as Fig. 4.

The nitrogen grain production efficiency of D-4 nitrogen increased with the increase of nitrogen application rate, and the nitrogen grain production efficiency of D-2 and B-1 decreased gradually with the increase of nitrogen application rate, and nitrogen grain production efficiency of C-9 reached a maximum in 225 kg N/ha. The nitrogen grain production efficiency of D-2 reached the highest, followed by B-1, in 150 kg N/ha. The nitrogen grain production efficiency of C-9 reached the highest in 225 kg N/ha. The nitrogen grain production efficiency of D-4 reached the highest

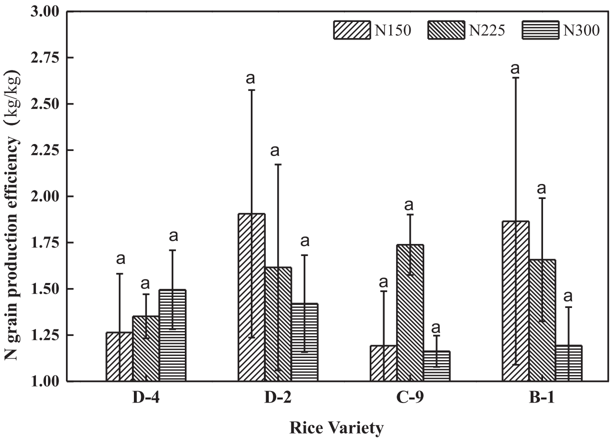

Fig. 4. Changes in nitrogen grain production efficiency.

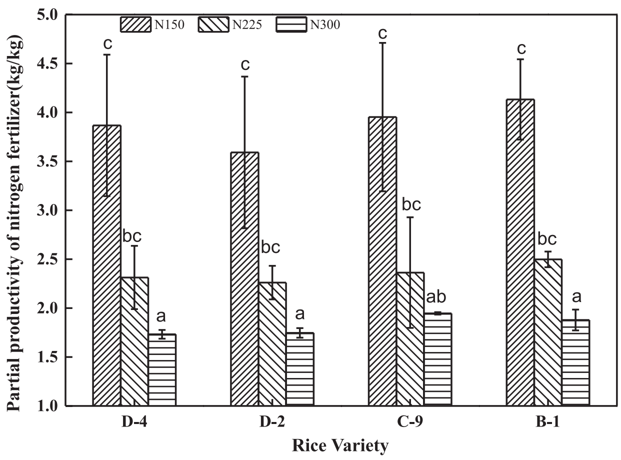

Fig. 5. Changes in partial productivity of nitrogen fertilizer.

in 225 kg N/ha. This trend and the trend of yield and yield components are inconsistent. This may be due to the fact that field experiments are affected by many factors and there is a big error. However, we can see that there was no significant difference in the nitrogen grain production efficiency of 4 rice varieties.

Changes in the Partial Productivity of Nitrogen Fertilizer

The partial productivity of nitrogen fertilizer of 4 rice varieties under 3 nitrogen application rates are shown in Fig. 5.

The partial productivity of nitrogen fertilizer of 4 rice varieties reached the maximum in 150 kg N/ha. With the increase of nitrogen application rate, partial factor productivity of applied nitrogen of 4 rice varieties all decreased. There was no significant difference between the partial productivity of nitrogen fertilizer of 4 rice varieties in 150 kg N/ha and 225 kg N/ha. Under different nitrogen application rates, the partial productivity of nitrogen fertilizer in the same kind of rice was significantly different. In particular, the difference between N300 and N150 was significant among the same kind of rice. There are differences, but they are not significant between the partial productivity of nitrogen fertilizer of 4 rice varieties in 150 kg N/ha and 225 kg N/ha.

Discussion

The accumulation of dry matter in rice is the basis for the construction of vegetative organs and the formation of grain yields, while rice material production capacity is largely influenced by the level of nitrogen nutrition [25]. In this experiment, the biomass (aboveground dry weight) of the four kinds of rice under different nitrogen application rates accumulated over time. Four varieties of rice under different nitrogen application rates, biomass on July 15 after the rapid growth stage until September 15, indicating that the amount of moderate nitrogen fertilizer, the accumulation of dry matter in the first and middle period, after the spikes from the vegetative organs transport from the photosynthetic products are more, so the total dry matter accumulation, in order to achieve high yield provides a solid material basis. In September, the biomass of D-4 and D-2 were highest in 225 kgN/ha; the biomass of C-9 and B-1were highest in 300 kg N/ha, indicating that nitrogen deficiency or nitrogen concentration is too high and will inhibit the growth of rice, affecting dry matter accumulation. This is also related to different rice varieties. Moderate nitrogen application level, medium and late have higher dry matter productivity, not only accumulated before the accumulation of more storage material, after heading also produce more net photosynthetic products, which is consistent with previous studies [47].

In recent decades, the relationship of N and salinity in plants has been reviewed [48-49]. Some studies noted that when the degree of salinity was not severe, N application improved plant growth and yield [50-51], while others revealed that at a given salinity level, N application improved plant growth in the deficient treatment only [52]. Recently, Semiz indicated that optimal N application was not necessary under higher saline conditions for pepper crop because the lower biomass accumulated under saline stress reduced the total N requirement. In general, with the increase in the amount of nitrogen fertilizer, the effect of nitrogen fertilizer increased first and then decreased, in line with the law of diminishing returns [53]. In this experiment, there was not a significant difference between the yield of four kinds of salt-tolerant rice under the different nitrogen application rates, which shows that all four kinds of rice can tolerate salt and alkali. The yield of four salt-tolerant rice plants reached the highest at the 150 kg N/ha treatment, indicating that under the condition that the salinity is too high, a large number of nitrogen fertilizers are not conducive to the increase in rice yield. The optimum nitrogen application rates for the four salinity-tolerant rices was the 150 kg N/ha treatment. Although the yield difference is not significant, D-4 is better than the other growth, and the yield of D-4 was the highest in the four rice treatments in 150 kg N/ha, indicating that D-4 compared to the other three kinds of rice was more suitable for growth in the saline-sodic environment. This may be due to its larger number of effective grains per spike and higher nitrogen use efficiency. According to previous studies, when the salt content is at a low level, the increase of nitrogen fertilizer can obviously increase crop yield, when the salt content is high, excessive nitrogen fertilizer will increase soil salinization, further inhibiting the growth of the crop and block the transfer of nitrogen [54]. Under the low nitrogen level, with the increase of nitrogen fertilizer, the effective number of grains per spike, yield, biomass, and nitrogen accumulation in rice per unit area was increased, but the amount of nitrogen applied to a certain level, with the increasing of nitrogen decreased. The optimum nitrogen application rate in this experiment is N150, which is consistent with the research of Lu Yanhong [55].

Studies have shown that the increase in rice yield is associated with the increase in yield attributes. When N was deficient, yield components were reduced – especially in panicle number per plant and per unit-area [56], fertilizer increases in production of rice mainly depend on the increase in the number of grains per panicle and the number of spikes [57]. This study indicated that the number of spikes and the number of effective grains per spike of four kinds of rice decreased with the increase of nitrogen application generally. This trend is consistent with the trend of rice yield, and shows that increasing rice yield comes mainly from increasing the number of spikes and the number of effective grains per spike. This is similar to previous studies. According to previous studies, the increase in panicle number per plant and per unit-area weight after the application of nitrogen fertilizer may be due to better nutrient availability and uptake by plants [58-59]. Therefore, the rational application of nitrogen fertilizer is to increase the yield of the important ways with the increase of nitrogen application rate, the 1000-grain weight of four kinds of rice increased with the increase of nitrogen application rate, which is inconsistent with the trend of rice yield. This study shows that 1000-grain weight is a factor that has little effect on yield, which is consistent with previous findings [60]. With the increase of nitrogen application rate, the ratio of primary and secondary branches of rice showed an upward trend under the same variety. According to Liu Lihua, there was no significant correlation between the number of branches, the number of secondary branches and yield, and the correlation with other indexes was significant or extremely significant [61], indicating that a branch and secondary branch is a factor that has little effect on yield; this study is similar to previous studies.

The nitrogen uptake of four salt-tolerant rice varieties showed an increasing trend. Appropriate increase of nitrogen fertilizer can increase the grain and straw N content, as well as grain and straw in the accumulation of nitrogen. Research has shown that there was a significant positive correlation between total nitrogen content in soil and protein content in rice [62]. The N uptake of C-9 and B-1 was the highest in August in 225 kg N/ha. The N uptake of D-4 and D-2 reached the maximum on September. The above characteristics may be related to the different characteristics of different rice varieties. The uptake of nitrogen by rice is not only related to the amount of nitrogen fertilizer [63], but also influenced by nitrogen fertilizer strategy and fertilizer type [64]. In September, the N uptake of D-4 reached the maximum in 150 kg N/ha and in 225 kg N/ha. The N uptake of C-9 reached the maximum in 300 kg N/ha. The accumulation of nitrogen in rice is mainly distributed among the grains in the mature stage. A large number of basal and tillering fertilizer inputs, reducing the accumulation of fertilizer nitrogen in the grain, which is mainly due to straw "luxury" caused by nitrogen [65], the application of nitrogen fertilizer was not only beneficial to the formation of rice crop yield, but also promoted the uptake of nitrogen and the transfer of grain to the grain. When the amount of fertilizer was enough to promote the uptake of nitrogen by plants, but was not conducive to the transfer of nitrogen to grain; when increasing the amount of nitrogen, it is not good for the absorption of nitrogen and the transfer of nitrogen to grain, the mechanism of nitrogen absorption by rice should be studied further. Therefore, for different salt-tolerant rice varieties, the application of nitrogen fertilizer should be treated differently. It is necessary to consider the maximum potential of the species itself, but also not too much nitrogen, resulting in higher accumulation of biomass, and seed yield will be down. Nitrogen application significantly increased the nitrogen uptake of rice and was mainly distributed in rice, which was consistent with Guo [66]. Therefore, it is necessary to consider the factors of rice yield and the efficiency of nitrogen fertilizer in different varieties.

The nitrogen grain production of D-4 increased with the increase of nitrogen application rate, the nitrogen grain production of D-2 and B-1 decreased with the increase of nitrogen application rate, and the nitrogen grain production of C-9 reached the highest in225 kg N/ha, which is related to different rice varieties. According to previous studies, the nitrogen translocation and nitrogen transport rate of stems and leaves of japonica rice cultivars with dwarf and high-yield were significantly higher than those of japonica rice cultivars with high stem and low-yield [67]. Nitrogen translocation rate in stem and leaf of rice cultivars with high nitrogen grain production was 42.71% higher than rice cultivars with low nitrogen grain production [68]. The higher the nitrogen grain production, the smaller the nitrogen ratio in the stem, sheath, and leaf of rice, the ratio of nitrogen in panicle is bigger. In particular, the percentage of nitrogen in stem, sheath, and leaf decreased more during the fruiting stage, the proportion of nitrogen in spike increased more, and the higher the nitrogen grain production [69]. It can be seen that there is a significant positive correlation between nitrogen translocation rate of rice in the whole plant and nitrogen grain production [70]. According to the experimental study, when the yields of B-1 and D-2 were highest, the nitrogen grain production was highest, while D-4 and C-9 were not. According to previous studies, it is shown that at any nitrogen level, the higher grain yield, higher total panicle per panicle, higher seed setting rate, higher harvest index and higher nitrogen harvest index, higher nitrogen dry matter production efficiency material, it is generally expressed as higher nitrogen grain production efficiency [71]. In this experiment, there was no significant difference in the nitrogen grain production of the four rice cultivars under different nitrogen application rates, the trend of nitrogen grain production efficiency is not exactly the same as the trend of rice yield. This shows that in the field experiment, the process of nitrogen accumulation in rice is also affected by many other factors, at the same time there are also large errors. According to previous studies, the salinization of soil inhibited the operation of rice nitrogen to the aerial part of rice plants, and the higher the nitrogen application rate, the more obvious the inhibition, which is related to the negative effect of nitrogen salt interaction [72], in this study, with the increase of nitrogen application rate, the partial productivity of nitrogen fertilizer decreased, which indicated that reducing the application rate of nitrogen fertilizer was one of the ways to improve nitrogen use efficiency, which is consistent with previous findings. However, if the nitrogen is too low it leads to the decrease of rice yield, so it is necessary to take into account both in actual production. Zhu Zhaoliang and other nitrogen efficiency parameters of 199 rice varieties showed that with the increase of nitrogen application rate, nitrogen use efficiency decreased [19], according to the results of the study on wheat, the nitrogen use efficiency decreased with the increase of nitrogen supply level [73]. The results of this study are consistent with the above findings. Studies have shown that nitrogen use efficiency is significantly positively correlated with yield. The results of this study show that the highest yield of rice at low nitrogen levels also confirms this view. Therefore, considering the high yield of rice and the efficient use of nitrogen fertilizer, the application of 150 kg N/ha under the experimental conditions is more appropriate.

In summary, the rational application of nitrogen fertilizer is an important measure to ensure the high yield of rice, and the effect of nitrogen fertilizer in saline-sodic soil is worth further study in the future. From the section of the increase in yield, improving fertilizer utilization, reducing ecological pollution, and increasing net income and other considerations should be based on different rice and the appropriate amount of nitrogen fertilization necessary to achieve improved nitrogen use efficiency and improve the yield effect.

Conclusion

In the experiment, biomass of four varieties of rice under different nitrogen application rates were accumulated over time, biomass on July 15 after the rapid growth stage, until September 15. The yield of four salinity-tolerant rices reached the highest at 150 kg N/ha. Compared with the other three kinds of rice, D-4 was more suitable for growth in a saline-sodic paddy field. The effect of nitrogen fertilizer production is mainly by increasing the number of spikes and the number of effective grains per spike. Applying nitrogen fertilizer reasonably can promote the uptake and transfer of nitrogen to the plants. When a certain amount of nitrogen was applied, it was not conducive to the uptake of nitrogen by plants, but also to the transfer of nitrogen to grains. The higher grain yield, higher total panicle per panicle, higher seed setting rate, higher harvest index, and higher nitrogen harvest index, higher nitrogen dry matter production efficiency material, it is generally expressed as a higher nitrogen grain production efficiency; however, according to this experiment, it is also affected by other factors under the field and there is an error. With the increase of nitrogen application rate, the partial productivity of nitrogen fertilizer decreased, the application of 150 kg N/ha under the experimental conditions is more appropriate.

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Conflict of Interest

The authors declare no conflict of interest.

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