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THE EFFECT OF NITROGEN RATE ON RICE TILLERING AND GRAIN YIELD UNDER WATER SAVING IRRIGATION

Suli XING[1], Tuo ZOU[2], Junfang YANG[1], Liangliang JIA[1], Yunma YANG[1], Limei ZHAI[3]

[1]Institute of Agro-resources and Environment, Hebei Academy of Agricultural and Forestry Sciences, Shijiazhuang, 050051, China
[2]Institute of Coastal Agriculture, Hebei Academy of Agricultural and Forestry Sciences, Shijiazhuang, 050051, China
[3]Institute of Agricultural Resources and Regional Planning, CAAS, Beijing, 100081, China

Corresponding author email: 834591172@qq.com

Abstract

In order to study the best nitrogen regime under water saving irrigation condition, an experiment was conducted based on completely randomized block design with 3 replications on rice at Caofeidian, north of China in 2018. There were six treatments, that was five levels of nitrogen (CK0 = 0, T1 = 217.8, T2 = 254.1, T3 = 290.4 and CK1=363 kg ha^{-1} i.e. farmers' traditional practice) under water saving condition of optimize alternate wetting and drying irrigation (OAWD) water 10,800 m^3 ha^{-1}, compared with farmers' practice nitrogen level of 363 kg ha^{-1} under farmers' traditional irrigation practice water13,800 m^3 ha^{-1} (CK2) as check. The results clearly indicated that excess nitrogen and water influenced negatively the productive tillers. Whereas proper nitrogen rate under OAWD irrigation enhanced the grains number of per panicle, filled grains percentage, grain yield and benefit. Compared to CK2, the treatment T2 was of good economic and ecological benefits with a significant higher of population panicles by 5.37%, of productive tillers percentage by 18.81%, of filled grains per panicle percentage by 6.88%, of grain yield by 8.72% and of benefit by 4146.15 yuan ha^{-1}, in addition, it was of an decrease of nitrogen dose by 30%, of fertilizer cost by 261.36 yuan ha^{-1} and of irrigation water by 21.7%.

***Key words**: rice, nitrogen regime, optimize alternate wetting and drying irrigation, tillering, grain yield.*

INTRODUCTION

Rice is the most water consumption crop under the condition of famers' traditional growing experience, 80% of irrigation water was lost by evaporation and leaching. Whereas, it is leading to a lot of waste on both fertilizer and irrigation water resources due to over-using on fertilizers and water resources with the decreasing nitrogen use efficiency. Especially in north China rice growth area, the contradiction between excess nitrogen fertilizer, excess irrigation water and shortage of water for rice production will be problem limiting rice development (Bolun, 2008; Ningning, 2011). Earlier reports observed limiting some water increased tillers and grain yield (Dordas, 2008; Sulin, 2018; Baocheng, 2011), while interaction of limiting water and nitrogen levels will be an effectively help for the growth of rice. The present study mainly compared the tillering, grain yield and benefit at variables doses of nitrogen under water saving irrigation with a view to better understanding for the best management of rice fertilization and irrigation in China north rice growth area.

MATERIALS AND METHODS

Study area and experiment design

A field experiment was conducted in the China season of 2018 at Caofeidian, Tangshan city, north of China. There was six treatments, that was five levels of nitrogen (CK0 = 0, T1 = 217.8 kg ha^{-1}, T2 = 254.1 kg ha^{-1},T3 = 290.4 kg ha^{-1} and CK1 = 363kg ha^{-1} i.e. farmers traditional practice) under water saving condition of optimize alternate wetting and drying irrigation (OAWD), compared with farmers' practice nitrogen level of 363 kg ha^{-1} under farmers' traditional irrigation practice as check. The treatment was arranged in random design and replicated three times. Unit plot was 48 m^2. Seedlings were planted on June 10, 2019 and harvested on October 30 in raw 29.6 cm and the distance 18.5 cm with 3 to 5 plants. A blanket rate fertilizer at 60 kg P_2O_5, 75 kg K_2O ha^{-1} was applied uniformly in all the plots and thoroughly incorporated into the soil at the time of final land preparation. Nitrogen was applied as per treatments in the form of urea in 5 times (first the time final land preparation, the next was continues 3 times top dressing from the first time that is 10 days after transplant with 10 days intervals up to the maximum tillering stage, the last top dressing was done at panicle initiation stage), Phosphorous was applied in the form of superphosphate and potassium was applied in the form of potassium sulfate.

Refer to the irrigation, the farmers' traditional practice irrigation maintained a layer of water of 7 to10 cm after transplanting, irrigated 18 times during the growth period with irrigation water 13,800 m^3 ha^{-1}, whereas OAWD irrigation regime operated be consistent with the need of different growth stages of rice tried to encourage or controlling tillering and growth. For example, the depth of the water layer kept 2 to 3 cm at transplant stage, followed 3 to 5 cm after planting, then 2 to 3 cm water layer at the beginning of tillering, next limited water and aired field in the late tillering stage to control the vegetative growth, after that at the panicle differentiation initiation stage 2 ~ 3cm was kept, followed aired field after the panicle differentiation, then kept water layer 2 to 3cm at milk initiation stage, and started airing field again at the medium dough stage to maturity. Total irrigation was 10,800 m^3 ha^{-1}. The precipitation through the growth period of rice was 440.9 mm, and the annual rainfall was 542.9 mm, of which the rainfall was 421.3 mm in July, August, and September, accounting for 77.6% of the annual rainfall, and 95.55% of the growth period (Figure 1). In addition, intercultural protection measures were taken as and when necessary.

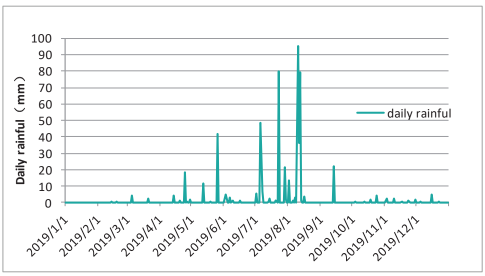

Figure 1. Daily rainful of the year 2019 at study area

Sampling methods

For the determination of growth and other characters, plants were observed in the plots at regular intervals. At each sampling, 10hills per plot were marked in the third row avoiding the border effect. The number of tillers in each 10hills was counted and means of each hill were recorder, grain yield of rice was determined by harvesting a sample area of 30 m^2 in the middle of each plot.

RESULTS AND DISCUSSIONS

Tillering deveopment

Less or excess nitrogen fertilizer rate exerted significant influence on the tillers production, retention and the tillering peak time of reaching at the maximum tillers number through growth stages (Figure 2). All treatments started speed tillering stage on June 19. Tillers peak of CK0 emerged on July 1 with the largest tillers number 1628,900 ha^{-1}, whereas peaks of treatments T1 and T2 emerged on July 8 with tillers number of 2200,230 ha^{-1} and 2310,700 ha^{-1}, respectively, then peaks of treatments T3, CK1 and CK2 emerged on July 15 with tillers number 2483,600 ha^{-1}, 2615,000ha^{-1} and 2556,600 ha^{-1}, respectively. This was rather expected because all the treatments applied nitrogen produced larger number of tillers than CK0 without nitrogen, meanwhile, under the uniform OAWD irrigation condition, the number of tillers per unit area increased gradually with the increase of nitrogen dose at the earlier tillering stage before July 15. Tiller mortality began past the maximum tillering stage and the number of tillers per unit area declined gradually reaching the lowest at maturity stage.

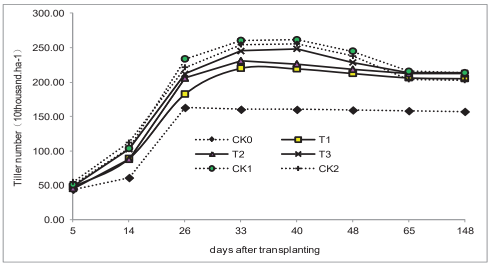

Figure 2. Tillering of different treatments

The percentage of unproductive tillers
It was discernible in Figure 3 that treatment CK0 was of the lowest percentage of unproductive tillers 2.32% at maturity, it was most likely caused by the minimum tillers number. Apart from CK0, treatment T2 was of a lower percentage of unproductive tillers of 6.80% and a higher productive tillers percentage of 93.20%, followed treatment T3, next CK1, then the percentage of unproductive tillers of the check treatment CK2 was highest. It implied both nitrogen dose and irrigation water exerted influence on the percentage of productive tillers and unproductive tillers, the productive tillers number i.e. panicles number per unit gradually increased with the nitrogen fertilizer rate increasing under the OAWD irrigation, excess nitrogen fertilizer dose negatively influenced the number of productive tiller. At the same time, excess irrigation water negative affected the number of panicle per unit population due to inhibition of tillering. The treatment T2 was of an increase productive percentage by 18.81% compared as the check CK2. It also shows proper nitrogen dose together with OAWD promoted productive tillering whereas decreased unproductive tillering.

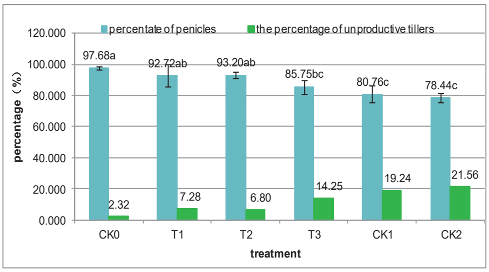

Figure 3. The percentage of unproductive tillers

Grain yield
Grain yield in rice as observed at maturity stages are shown in Table 1. Grain yield varied between 8404.20 kg ha^{-1} and 11439.10 kg ha^{-1}. Treatment T2 produced the maximum grain yield, while CK0 produced the least. A closer look at the results reveals that the rice grain yield tended to increase linearly with increasing rate of applied nitrogen under OAWD irrigation at maturity stage, T2 treatments with application of 254.1 kg N produced statistically higher grain yield than other treatments. As for treatment T3 and CK1 the further increase in N rates caused lower grain yield. Akita (1989) reported that excess nitrogen gave higher dry weight at heading causing a yield decline due to reduced ripening percentage. Compared to CK2, treatment T2 produced a significant higher grain yield by 8.72%. In additional, under the excess nitrogen fertilizer, the grain yield of OAWD irrigation CK1 was of a little higher than that of farmers' traditional practice irrigation of CK2 by 1.11%, which indicates that the optimized dry and wet alternating management way was of the effect both on saving water and stabilizing production output.

Table 1. Effects of different treatments on grain yield and yield components of rice

Treatments	Panicles number per ha (10 thousand ha^{-1})	Grains number per panicle	Filled grain percentage (%)	Grains weight per thousand (g)	Yield Theoreticle Calculated (kg ha^{-1})	Grain yield harvested (kgha^{-1})
CK0	156.57d±4.21	195.25c±1.68	79.47c±1.27	33.09a±0.73	8037.10c±246.44	8404.20c±264.76
T1	203.85bc±2.85	239.81b±8.25	81.35b±0.98	31.51bc±1.21	12516.64b±778.93	10988.55a b±317.23
T2	211.35a±3.12	252.59a±2.69	85.48a±1.24	32.10ab±0.36	14456.10a±345.10	11439.10a±246.86
T3	209.80ab±1.60	249.13a±7.64	82.91b±0.61	31.63bc±0.49	13701.46a±456.79	11038.85a b±305.51
CK1	210.92ab±5.91	248.22ab±4.68	80.36c±0.14	30.47c±0.54	12814.11b±369.18	10638.65b±251.94
CK2	200.58c±5.09	247.71ab±2.11	79.97c±1.47	31.29bc±0.94	12430.55b±435.66	10521.88b±431.28

Grain yield factors
Proper nitrogen dose and irrigation allocation significantly increased the panicles number of per ha., grains number per panicle, and filled grain percentage at maturity stage was observed in Table 1.
Treatment T2 produced the highest 2113,600 panicles per ha. with a significant higher of 5.37% compared to the farmers traditional practice CK2. Followed by CK1, T3, T1, CK2 and CK0 gave the least. Variation of the panicles number of per ha. perhaps due to the increasing of nitrogen under the uniform OAWD irrigation. On the contrary, the excess water is of negative influence on the productive tillers number i.e. panicles number.
The sort order of grains number per panicle was observed as T2> T3> CK1> CK2> T1> CK0. Among them, the treatment CK0 produced the least panicle grain number, significantly lower than that of other treatment, whereas treatment T2 produced the biggest grain number with average 252.59 per panicle,

it was of a little higher by 1.97% compared with CK2, and the difference was not significant.

The filled grain percentage was ranked as T2> T3> T1> CK2> CK1> CK0, evidently proper nitrogen dose and OAWD irrigation interaction enhanced the filled grain percentage to a certain extent. Both excess or inadequate nitrogen fertilizer and water exerted a negative influence on the grain filling. The treatment T2 produced a significant higher filled grains percentage by 6.88% compared with CK2.

The sort order of grains weight per thousand was CK0> T2> T3> T1> CK2> CK1, and the difference between T2 and CK1 was significant, indicated that a reasonable combination of nitrogen and water increased the grain weight per thousand. Excess or insufficient nitrogen fertilizers affected the grains weight. Whereas rrigation helped produce grains weight per thousand.

Compared with farmers' traditional practice water and nitrogen management CK2, T2 significantly increased the number of population panicles by 5.37%, increased the grains number per panicle by 1.97%, significantly increased the filled grain percentage by 6.88%, and had no significant effect on the grain weight per thousand.

Benefit

Table 2 indicated the cost and benefits performance of rice from different treatments.

Table 2. Effects on benefit of rice of different treatments（Yuan·ha^{-1}）

Treatments	Gross income, Yuan • ha^{-1}	Cost（Yuan • ha^{-1}）			Benefit（Yuan • ha^{-1}）
		fertilizer	irrigation	others	
CK0	21850.92	762.00	3000.00	20437.50	-2348.58
T1	28570.23	1458.96	3000.00	20437.50	3673.77
T2	29741.66	1371.84	3000.00	20437.50	4932.32
T3	28701.01	1284.72	3000.00	20437.50	3978.79
CK1	27660.49	1633.20	3000.00	20437.50	2589.79
CK2	27356.88	1633.20	4500.00	20437.50	786.17

Note: the price per kg of rice: 2.6 yuan, nitrogen fertilizer: 2.4 yuan, P_2O_5: 5.0 yuan and K_2O: 6.0 yuan. Others cost 20437.5 yuan per ha include 375.0 yuan for tilling plots, 525.0 yuan for harrowing plots, 375.0 yuan for making plots flat, 2062.5 yuan for seedlings, 450.0 yuan for pesticides, 150.0 yuan for making furrows, 12,000.0 yuan for field be rented, and 4500.0 yuan for labor.

Apart from CK0, benefit varied between 786.17 yuan per ha. to 4932.32 yuan per ha. The treatment T2 was of a higher benefit 4141.15 yuan per ha. compared to the farmers' practice CK2. In addition, a review from the experiment design showed the treatment T2 was of a decreased of nitrogen fertilizer by 30% with fertilizer cost of 261.36 yuan per ha., and saved irrigation water by 21.7% compared to CK2.

Water and nutrients are two important factors affecting rice tillering. If tillers were produced earlier and generated at a low position on stem, and it would be helpful to grain yield (Hanliang, Z.H., 2000; Qinghe, C.H., 2008). Rice tillering stage is more sensitive to water. If the water layer is too deep, it would affect normal tillering. Shallow irrigation is helpful for tillering. Reports indicated that when the temperature was around 26-33°C and the soil water holding capacity is 80%, tillers were the most, on the contrary, when the temperature was lower than 20°C and the soil water capacity reached 100%, tillers were the least (Shou, 2008; Manli and Guowei, 2017). OAWD irrigation promoted tillering by controlling the irrigation according to rice demand for water in different periods of rice, so tillers number for each growth stage and numbers of population panicles at maturity of CK1 were higher than that of CK2, it discernible a significant promotion effect on productive tillers of rice. In addition, nutrients are also important factors influencing tillering of rice. The rate of nitrogen applied to rice affects the number of tillers and productive tillering. If nitrogen applied is excessive, the peak of tillering is delayed, and when the rate of nitrogen applied increasing, the number of unproductive tillers growing, whereas the productive tillers decreasing, it affects the grain yield.

Reports showed that the water demand of rice plants would be 2310 m^3 per ha. through the growth period, accounting for 11% of the total water consumption, and the evaporation would be 3735 m^3 per ha., accounting for 17% whereas leakage would be15660 m^3 per ha, accounting for 72%. It can be seen that a large amount of irrigation water for rice is consumed by evaporation and leakage (Chu, 2016; Weiguang, 2013; Fuqiang, 1999). At the same time, with a lot of loss of irrigation water, the