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Influence of Irrigation Scheduling with Levels and Times of Nitrogen Application on Root Growth of Aerobic Rice

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Abstract

Aerobic rice is one of the alternative methods for saving water, energy, labour, time and reduced methane gas in rice production ecosystem. The field experimental trial was conducted during summer 2018 at Agricultural College and Research Institute, Madurai. Irrigation scheduling based on different IW/CPE (Irrigation Water/Cumulative Pan Evaporation) ratios and different doses along with various spilt applications of nitrogen were experimented. Results of field experiment indicated that irrigation scheduling at IW/CPE of 0.8 up to panicle initiation stage and thereafter IW/CPE of 1.0 up to dough stage recorded the highest root length of 13.0 cm at active tillering and 18.8 cm at flowering stage. But, irrigating the aerobic rice at IW/CPE of 1.0 up to panicle initiation stage and thereafter IW/CPE of 1.2 up to dough stage recorded the highest root volume (16.9, 27.1 cc·hill^{-1}) and root dry weight (6.1, 12.9 g·hill^{-1}) at active tillering and flowering stage. Application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS (Days after sowing) recorded the highest root length of 13.5 cm, root volume of 17.6 cc·hill^{-1} and root dry weight of 6.4 g·hill^{-1} at active tillering stage and root length of 19.4 cm, root volume of 27.6 cc·hill^{-1} and root dry weight of 14.4 g·hill^{-1} at flowering stage. The interaction effect of irrigation and nitrogen significantly influenced the root growth. Irrigation at IW/CPE of 0.8 up to panicle initiation stage and thereafter IW/CPE of 1.0 up to dough stage along with 150 kg N ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS significantly enhanced the root length (15.7, 23.6 cm) at active tillering and flowering stage. However, irrigation scheduling at IW/CPE of 1.0 up to panicle initiation stage and thereafter IW/CPE of 1.2 up to dough stage along with application of N 150 $kg \cdot ha^{-1}$ in 5 equal splits at 20, 35, 50, 65 and 80 DAS registered the highest root volume (20.3, 32.8 $cc \cdot hill^{-1}$) and root dry weight (8.3, 16.4 $g \cdot hill^{-1}$) at active tillering and flowering stage.

Keywords

Irrigation, IW/CPE Ratio, Nitrogen, Root Growth, Aerobic Rice

1. Introduction

Rice is the staple food for half of the world population and grown area is 158.5 million hectares with a production of 470.6 million tons and productivity of 4.43 $t \cdot ha^{-1}$. India is the second largest producer (103.5 million tons) of rice after China (145.7 million tons) [1]. However, additionally rice has to be produced at rate of 1.7 million tonnes per year to sustain the national food security [2]. In India, urbanization and rapid increases in population are gradually deteriorating the availability of water for agriculture. Groundwater tables have dropped on an average by 0.5 - 0.7 $meter \cdot year^{-1}$ in the Indian states of Karnataka, Maharashtra, Rajasthan, Punjab, Haryana, northern Gujarat and Tamil Nadu [3]. This forces the farmers to look in for alternative methods of irrigating rice crop for sustaining rice production. Aerobic rice is a water saving method of growing rice by direct seeding of high yielding varieties in un-puddled condition without standing water and irrigated similar to other upland cereal crops [4].

Proper scheduling of irrigation is needed for more efficient use of water and to increase the shoot and root growth, for increased yield [5]. In irrigation scheduling, climatological approach based on IW/CPE ratio has been found to be the most appropriate method. This approach integrates all the weather parameters that determine water use by the crop [6]. Normally, aerobic rice culture promotes lateral root branching and deep rooting compared to transplanted rice [7]. Rice plants grown under intermittent irrigation management had higher root activity under aerobic conditions [8]. Nitrogen fertilization should be balanced between maximizing yield and minimizing the risk of lodging in rice crop. Nitrogen fertilization with proper time of application is the major agronomic practice that affects the growth and yield of rice crop [9]. Application of nitrogen in splits according to crop requirement causes not only reduces the loss of nitrogen but also increased the nitrogen absorption by higher root growth [10]. In aerobic system, the dominant form of nitrogen is nitrate and relatively little ammonia volatilization is expected after nitrogen fertilizer application [11]. A major problem of irrigated rice systems is the increasing water scarcity. In fact, the water scarcity is threatening Asia's irrigated rice production system and rice is very sensitive to water stress and attempts to reduce water inputs may result in growth and yield reduction. The challenge is to develop novel technologies and production to be maintained in the face of declining water availability. The response of root growth dynamics to irrigation managements is well understood in flood culture of rice cultivation. But in aerobic rice culture, the response of root growth to severe soil drying has been intensively studied [7]. However, information on potential of aerobic rice, suitable irrigation management is lacking in Indian continent. Next to water, nitrogen is the most important factor for rice production. The crop response to nitrogen application was observed up to 175 $kg \cdot ha^{-1}$ in aerobic rice [12]. However, such information is limited and there is a need to quantifying and optimizing the nitrogen doses at different growth stages. In addition, altering the split doses according to the crop requirement is also needed to be optimizing under aerobic rice cultivation with relation to root growth and activities. Hence, this experiment was conducted to study the influence of various irrigation scheduling and nitrogen levels and time of applications on root growth for aerobic rice.

2. Materials and Methods

2.1. Experimental Site, Design and Selection of Cultivar

Field experiment was conducted during the summer 2018 at Agricultural College and Research Institute, Madurai located at the southern agro climatic zone of Tamil Nadu, India. The experimental site is geographically located at 9˚54'N latitude and 78˚54'E longitude and at an altitude of 147 m above mean sea level. The field experiment was laid out in split plot design with three replications and variety ADT (R) 45 was used with a spacing of 20 × 10 cm. The population was maintained by gap filling and thinning. The soil of experimental site was sandy clay loam in texture. Irrigation water was measured through Parshall flume.

2.2. Treatment Details

Main plot: Irrigation scheduling

I_1—IW/CPE 0.8 throughout the growth stage

I_2—IW/CPE 0.8 up to panicle initiation stage and thereafter IW/CPE 1.0 up to dough stage

I_3—IW/CPE 0.8 up to panicle initiation stage and thereafter IW/CPE 1.2 up to dough stage

I_4—IW/CPE 1.0 throughout the growth stage

I_5—IW/CPE 1.0 up to panicle initiation stage and thereafter IW/CPE 1.2 up to dough stage

(*Note*: *IW*/*CPE—Irrigation Water*/*Cumulative Pan Evaporation*)

Sub plot: Nitrogen management

N_1—100 kg N: 4 equal splits at 20, 40, 60 and 80 DAS

N_2—100 kg N: 5 equal splits at 20, 35, 50, 65 and 80 DAS

N_3—125 kg N: 4 equal splits at 20, 40, 60 and 80 DAS

N_4—125 kg N: 5 equal splits at 20, 35, 50, 65 and 80 DAS

N_5—150 kg N: 4 equal splits at 20, 40, 60 and 80 DAS

N_6—150 kg N: 5 equal splits at 20, 35, 50, 65 and 80 DAS

(*Note*: *N—Nitrogen*, *DAS—Days after sowing*)

2.3. Statistical Analysis

The observed data on crop were statistically analysed by following the procedure for split plot design as described by Gomez and Gomez [13]. Analysis was done with the help of "AGRIS" software. Critical differences (C.D) were worked out at five per cent probability level to check the significance of treatment's mean. The treatment differences that were non-significant at five per cent were denoted as NS.

2.4. Observations

2.4.1. Root Length

The entire hill along with root intact with the soil was scooped carefully and washed in running water. The root length was measured from base to tip of the longest root and expressed in cm.

2.4.2. Root Volume

The roots scooped along with the soil and washed in running water carefully. Root volume was found out by placing the root mass into a measuring cylinder containing a known volume of water. The increase in the water column was assessed and expressed as cc·hill^{-1}.

2.4.3. Root Dry Weight

The sampled plant's root were collected, cleaned in running water and dried in hot air oven at 70˚C ± 20˚C till it reached a constant weight and expressed as g·plant^{-1}.

3. Results and Discussion

Irrigation scheduling of IW/CPE 0.8 up to panicle initiation and thereafter IW/CPE 1.0 up to dough stage (I_2) recorded the highest root length (13.0 cm) at active tillering stage and (18.8 cm) at flowering stage (**Table 1**). Increased root length under lesser IW/CPE ratios may be an added advantage to combat stress under water limitation condition as reported earlier by Matsuo *et al*. [14] and Parthasarathi *et al*. [15]. However, significantly higher root volume (16.9, 27.1 cc·hill^{-1}) and root dry weight (6.1, 12.9 g·hill^{-1}) at active tillering and flowering stage were recorded when irrigation at IW/CPE of 1.0 up to panicle initiation stage and thereafter IW/CPE of 1.2 up to dough stage (I_5) compared to all other irrigation scheduling treatments (**Table 1**). This might due to maximum water content in tissue which increases the turgidity and dense proliferation of roots at top layer due to favourable moisture conditions [16]. The lowest root volume (13.7, 19.1 cc·hill^{-1}) and root dry weight (2.8, 8.3 g·hill^{-1}) recorded in the treatment of irrigation at IW/CPE of 0.8 throughout the growth stage (I_1). This was due to increased severity of water stress [17] as water deficit reinforce many anatomical changes in the plant, including decrease in cell volume, cell division, cell elongation, intercellular space and thickening of cell wall their by limits the overall root growth.

The application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS (N_6) resulted in the highest root length of 13.5, 19.4 cm, root volume of 17.6, 27.6 cc·hill^{-1} and root dry weight of 6.4, 14.4 g·hill^{-1} at active tillering and flowering stage respectively (Table 1). The optimum dose and time of nitrogen supply throughout the crop growth period might have increased the root growth as reported by Maheswari *et al.* [18] and produced more dry matter that could produce additional photosynthates for the development of root system as earlier reported by Devi and Sumathi [19]. Application of nitrogen at 100 kg·ha^{-1} in 4 equal splits at 20, 40, 60 and 80 DAS recorded the lowest root length (11.0, 13.6 cm), root volume (13.6, 19.9 cc·hill^{-1}) and root dry weight (3.3, 8.2 g·hill^{-1}) at active tillering and flowering stage (N_1). This might due to insufficient supply of nitrogen for better root growth [20].

Interaction Effect (Irrigation *x* Nitrogen)

Among the different treatment combinations (Table 2), I_2N_6 *i.e.*, Irrigation at IW/CPE of 0.8 up to panicle initiation stage and thereafter IW/CPE of 1.0 up to

Table 1. Root parameters of aerobic rice as influenced by irrigation scheduling, levels of nitrogen and time of application.

	Active tillering stage			Flowering stage		
Treatments	Root length (cm)	Root volume (cc·hill^{-1})	Root dry weight (g·hill^{-1})	Root length (cm)	Root volume (cc·hill^{-1})	Root dry weight (g·hill^{-1})
			Irrigation Scheduling			
I_1	12.6	13.7	2.8	17.9	19.1	8.3
I_2	13.0	14.6	3.3	18.8	22.0	10.1
I_3	11.8	15.0	4.4	16.5	22.9	11.2
I_4	11.6	16.1	5.7	14.2	25.3	11.8
I_5	11.1	16.9	6.1	13.5	27.1	12.9
S.Ed.	**0.23**	**0.55**	**0.08**	**0.35**	**0.56**	**0.20**
C.D. (0.05)	**0.53**	**1.27**	**0.19**	**0.80**	**1.29**	**0.46**
			Nitrogen Management			
N_1	11.0	13.6	3.3	13.6	19.9	8.2
N_2	11.3	14.1	3.5	14.0	21.4	8.9
N_3	11.7	14.9	3.9	14.8	22.1	9.7
N_4	12.5	16.2	5.2	18.2	24.8	12.4
N_5	12.1	15.1	4.6	17.1	23.7	11.7
N_6	13.5	17.6	6.4	19.4	27.6	14.4
S.Ed.	**0.22**	**0.31**	**0.11**	**0.35**	**0.58**	**0.26**
C.D. (0.05)	**0.48**	**0.68**	**0.24**	**0.76**	**1.27**	**0.57**

Table 2. Interaction (I x N) effect on root parameters of aerobic rice as influenced by irrigation scheduling, levels of nitrogen and time of application.

	Active tillering stage			Flowering stage		
Treatments	Root length (cm)	Root volume (cc·hill^{-1})	Root dry weight (g·hill^{-1})	Root length (cm)	Root volume (cc·hill^{-1})	Root dry weight (g·hill^{-1})
I_1N_1	11.5	12.1	1.8	14.6	18.6	6.2
I_1N_2	11.2	12.6	2.0	14.9	16.5	7.1
I_1N_3	12.6	13.7	2.4	15.4	17.8	7.8
I_1N_4	13.2	14.4	3.5	21.2	19.6	8.9
I_1N_5	12.7	13.8	3.1	19.5	19.2	8.1
I_1N_6	14.3	15.6	4.2	21.5	22.6	11.5
I_2N_1	11.8	13.2	2.2	15.2	19.5	7.8
I_2N_2	12.1	13.7	2.5	15.5	21.1	8.2
I_2N_3	12.5	15.1	2.9	16.6	21.5	8.7
I_2N_4	13.2	15.4	3.9	21.7	22.5	11.5
I_2N_5	12.9	14.2	3.4	20.2	21.7	10.6
I_2N_6	15.7	16.2	4.8	23.6	25.4	13.8
I_3N_1	10.8	13.8	2.8	13.5	20.4	8.5
I_3N_2	10.9	14.1	3.1	14.2	21.6	9.2
I_3N_3	11.1	14.4	3.7	14.6	22.3	9.6
I_3N_4	12.5	16.0	5.5	18.4	23.5	12.4
I_3N_5	12.0	14.8	4.5	17.6	22.6	12.2
I_3N_6	13.5	16.9	6.7	20.8	26.8	15.3
I_4N_1	10.9	14.8	4.6	12.6	19.5	8.9
I_4N_2	11.2	15.1	4.9	12.8	23.1	9.6
I_4N_3	11.3	15.7	5.0	13.5	23.5	10.5
I_4N_4	11.9	16.1	6.3	15.1	28.8	13.8
I_4N_5	11.7	15.8	5.7	14.8	26.3	13.4
I_4N_6	12.5	18.9	7.9	16.6	30.5	14.8
I_5N_1	10.2	14.3	4.9	12.0	21.7	9.4
I_5N_2	10.9	14.9	5.1	12.6	24.8	10.2
I_5N_3	11.0	15.5	5.5	13.7	25.3	11.7
I_5N_4	11.5	19.2	6.8	14.4	29.4	15.5
I_5N_5	11.3	16.9	6.2	13.5	28.6	14.2
I_5N_6	11.6	20.3	8.3	14.6	32.8	16.4
S.Ed.	**0.50**	**0.71**	**0.25**	**0.79**	**1.32**	**0.59**
C.D. (0.05)	**1.03**	**1.47**	**0.51**	**1.63**	**2.73**	**1.22**

dough stage along with 150 kg N ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS significantly enhanced the root length of 15.7 cm at active tillering and 23.6 cm at flowering stage. This was due to mild moisture stress and optimum supply of nitrogen throughout the crop growth period was resulted increased root length as earlier reported by Devi and Sumathi [19] and Mahajan *et al.* [21]. Irrigation at IW/CPE of 1.0 up to panicle initiation stage and thereafter IW/CPE of 1.2 up to dough stage along with application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS (I_5N_6) registered the highest root volume of 20.3, 32.8 cc·$hill^{-1}$ and root weight of 8.3, 16.4 g·$hill^{-1}$ at active tillering and flowering stage. This might due to continuous and optimum supply of nitrogen with presence of optimum soil moisture in the root zone throughout the crop growth period as reported earlier by Mandal *et al.* [22].

4. Conclusion

The present investigation reveals that irrigation scheduling with levels and time of nitrogen applications significantly influenced the root throughout the crop growth period. Irrigation scheduling of IW/CPE of 0.8 up to panicle initiation and thereafter IW/CPE of 1.0 up to dough stage along with application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS enhanced the root length. Irrigation scheduling of IW/CPE of 1.0 up to panicle initiation stage and thereafter IW/CPE of 1.2 up to dough stage along with application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS recorded the highest root volume and root dry weight. The availability of soil moisture with optimum level of nitrogen enhanced the root growth for obtaining higher nutrient uptake and yield of aerobic rice.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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