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Effect of Varied Irrigation Scheduling with Levels and Times of Nitrogen Application on Yield and Water Use Efficiency of Aerobic Rice

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Abstract

More rice needs to be produced with lesser water to feed the increasing human population. Judicious water management practices and appropriate water saving technologies in rice cultivation are in need in the coming decades. Aerobic rice is one of water saving method of rice cultivation. The field experiment was conducted during *Summer* season of February 2018 to May 2018 at Tamil Nadu Agricultural University, Agricultural College and Research Institute, Madurai, to find out the effect of irrigation schedules with varied doses and time of nitrogen application on yield of aerobic rice. Irrigation scheduling of IW/CPE (Irrigation Water/Cumulative Pan Evaporation) 1.0 up to panicle initiation stage and thereafter IW/CPE 1.2 up to dough stage recorded higher yield attributes *viz.*, number of panicles hill^{-1} (9.1), number of filled grains panicle^{-1} (87.9), test weight (15.3 g), grain yield (4462 kg·ha^{-1}), straw yield (5977 kg·ha^{-1}). However, the highest water use efficiency (6.8 kg·ha^{-1}·mm^{-1}) was recorded in the treatment of IW/CPE 1.0 throughout the crop growth period. Lower yield attributes, yield and water use efficiency were recorded with irrigation scheduling of IW/CPE 0.8 throughout the growth 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 higher yield attributes *viz.*, number of panicles hill^{-1} (9.3), number of filled grains panicle^{-1} (90.5), test weight (15.4 g), grain yield (4746 kg·ha^{-1}), straw yield (6258 kg·ha^{-1}) and WUE (7.5 kg·ha^{-1}·mm^{-1}). Application of nitrogen 100 kg·ha^{-1} in 4 equal splits at 20, 40, 60 and 80 DAS recorded lower yield attributes, yield and water use efficiency. The interaction effect between irrigation scheduling and nitrogen management on yield was significant. The combination of IW/CPE 1.0 up to panicle initiation stage and thereafter IW/CPE 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 significantly produced higher number of panicles hill^{-1} (10.7), grain yield of 5419 kg·ha^{-1} and straw yield of 6906 kg·ha^{-1}. However, IW/CPE 1.0 throughout the growth period along with application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS registered the highest water use efficiency (8.4 kg·ha^{-1}·mm^{-1}) in aerobic rice.

Keywords

Aerobic Rice, Irrigation, IW/CPE, Nitrogen, Yield, Water Use Efficiency

1. Introduction

Rice is the most widely consumed cereal grain on earth and is the staple food for over half of the world's population. Asia's food security depends mainly on irrigated lowland rice fields, which produce three-quarters of all rice harvested [1]. At present the productivity of Asia's irrigated rice systems is increasingly threatened by water scarcity. In the next 25 years, 15 to 20 million hectares of lowland rice in Asia are projected to suffer from water scarcity [2]. Hence, shifting gradually from traditional rice production system to growing rice aerobically, especially in water scarce irrigated lowlands, can mitigate the water deficient condition. Cultivation of rice by method of aerobic will save water as it is grown under non flooded conditions in non-puddled, unsaturated soil. Aerobic rice cultivation not only reduces the water requirement but also sustains the rice productivity. However, the major constraints which limit the yield of aerobic rice is high weed infestations [3], lesser nutrient availability and micro-nutrient deficiencies [4] [5]; and nematode infestations [6].

Scheduling of irrigation in irrigated dry aerobic rice plays a major role in obtaining higher yields as well as higher water productivity [7]. Effective tillers and grain yield of rice increased with the decrease in irrigation interval up to 5 days and any further decrease in irrigation interval did not prove beneficial [8] [9]. Nitrogen is the important and major nutrient in rice crop. Its efficiency can be improved by scheduling of irrigation and weed management. Optimum timing of nitrogen application coupled with irrigation scheduling would enhance the availability of nitrogen to the crops and increased the grain yield of rice in aerobic rice cultivation [10]. The grain yield, yield attributes, grain quality parameters and soil microbial activities were also influenced by split application of nitrogen [11]. Increased yield due to application of nitrogen with presences of optimum soil moisture in the root zone [12]. With these perspectives experiment was conducted to study the effect of irrigation scheduling and nitrogen doses along with split application influence the yield attributes and yield of aerobic rice.

2. Materials and Methods

2.1. Experimental Site and Design

To study the influence of irrigation scheduling and nitrogen management on performance of rice in aerobic condition, field experiment was conducted during *summer* 2018 at Agricultural College and Research Institute, Madurai (9˚54'N latitude and 78˚54'E longitude), Tamil Nadu, India. The field experiment was laid out in a split plot design. The spacing of rice was 20 × 10 cm. The soil of experimental site was sandy clay loam (pH-7.04, Ec-0.33 dS m^{-1} and Organic carbon-0.42 per cent). Rice variety ADT (R) 45 was used for the field experiment. Irrigation water was measured through Parshall flume in open irrigation channel.

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 the crop were statistically analysed by following procedure for split plot design [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. Number of Panicles Hill^{-1}

The numbers of panicle hill^{-1} were counted from five randomly tagged plants in each plot.

2.4.2. Number of Filled Grains Panicle^{-1}

The total numbers of filled grains in randomly selected panicles from the tagged plants were counted and the mean was expressed as numbers panicle^{-1}.

2.4.3. Test Grain Weight

From each plot, one thousand filled grains were collected at harvest. After drying to the moisture content of 14 per cent, the grains were weighed in an electronic balance and expressed in gram (g).

2.4.4. Grain Yield

The harvested plants from net plot area (15.1 m^2) were threshed manually from each plot and the harvested grain was separately sun dried, cleaned and weighed. Grain yield was computed at 14 per cent moisture and expressed in kg·ha^{-1}

2.4.5. Straw Yield

The straw obtained from each net plot area (15.1 m^2) was sun dried, weighed and expressed in kg·ha^{-1}

2.4.6. Water Use Efficiency (WUE)

Field water use efficiency (WUE) was computed using the equation suggested by Viets [14].

$$WUE = \frac{\text{Grain yield }\left(\text{kg}\cdot\text{ha}^{-1}\right)}{\text{Total water used to produce the yield }\left(\text{mm}\right)}$$

3. Results and Discussion

3.1. Yield Attributes

Irrigation scheduling of IW/CPE of 1.0 up to panicle initiation stage and there after IW/CPE of 1.2 up to dough stage (I_5) recorded significantly higher yield attributes *viz*., number of panicles hill^{-1} (9.1), number of filled grains panicle^{-1} (87.9) and test weight (15.3 g) (**Table 1**). However, irrigation scheduling of IW/CPE 1.0 throughout the growth stage (I_4) did not differ significant from the above treatment. This might due to increase leaf area; leading to higher photosynthates and accumulation of more assimilates which led to increased sink size [15]. Lower yield attributes was recorded with irrigation scheduling of IW/CPE 0.8 throughout the growth stage (I_1). Severe water stress conditions after imposition of irrigation schedules resulted in lower yield parameters and yield due to unfavourable conditions generated with the drying of rhizosphere as earlier reported by Rahman *et al*. [16]. Parihar [17] also observed that decreasing yield attributes with increasing irrigation intervals.

Application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS (N_6) recorded the highest number of panicles hill^{-1} (9.3), number of filled grains panicle^{-1} (90.5) and test weight (15.4 g) (**Table 1**). The supply of 150 kg N ha^{-1} was found significant in favouring structural and functional activities of the crop in aerobic condition [18]. The extended split application of nitrogen up to

80 DAS helped to meet the crop requirement and resulted not only in reducing the loss of nitrogen but also increased the nitrogen absorption, consequently better utilization of applied nitrogen resulting in higher yield attributes. This same phenomenon was reported earlier by Devi and Suamthi [19] in aerobic rice.

3.2. Yield

The yield of aerobic rice was higher with irrigation scheduling of IW/CPE of 1.0 up to panicle initiation stage and thereafter IW/CPE of 1.2 up to dough stage (I_5) with the highest grain yield of 4462 kg·ha^{-1} and straw yield of 5977 kg·ha^{-1} (**Table 1**). This increased yield was due to better availability of moisture, which in turn leads to efficient physiological activity. However, irrigation scheduling of IW/CPE 1.0 throughout the growth stage (I_4) did not differ significant from the above treatment in yield. The results of the experiment are in accordance with the results of Belder *et al.* [20] and Shekara *et al.* [21]. They explained that efficient translocation of photosynthates from source to sink might be responsible for the increased yield. Lowest grain and straw yield were associated with irrigation scheduling of IW/CPE ratio of 0.8 throughout the growth stage (I_1). The decreased yield was mainly due to severe moisture stress in the soil which led to reduced growth and physiological activities. Further it also interferes with the pollination, fertilization and grain filling as reported by Rao *et al.* [7].

Application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS (N_6) recorded higher grain yield of 4746 kg·ha^{-1} (**Table 1**) and straw yield of 6258 kg·ha^{-1} (**Table 2**). Application of 150 kg of nitrogen in five equal splits enhanced stature of growth and yield attributes, forming large sink size coupled with efficient translocation of photosynthates from source to sink, which would have registered in more of filled grains and there by increased the grain and straw yield [22] and [23]. The increased straw yield was due to higher uptake of nitrogen and resulted in the vigorous vegetative growth of rice, Mandal *et al.* [12] also reported such results. The split application of nitrogen enhanced the utilization of applied nitrogen and minimized the loss of nitrogen through leaching. This result was also conformity with the findings of Balasubramanian [24]. Application of nitrogen at 100 kg·ha^{-1} in four equal splits at 20, 40, 60 and 80 DAS (N_1) significantly resulted in lower grain and straw yield. This was due to lesser nitrogen availability under aerobic condition which resulted in reduced yield.

3.3. Water Use Efficiency (WUE)

The highest water use efficiency of 6.8 kg·ha^{-1}·mm^{-1} was recorded with the irrigation scheduling IW/CPE of 1.0 throughout the growth stage (I_4). This might due to increased grain yield and reduced water consumption when compared to the other irrigation scheduling treatments [25]. Application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS (N_6) registered the highest

WUE of 7.5 kg·ha^{-1}·mm^{-1} (Table 1). Increase in nitrogen levels resulted in higher WUE due to increased yield under higher nitrogen level [26].

3.4. Interaction Effect (*Irrigation x Nitrogen*)

The interaction effect between irrigation scheduling and nitrogen management were significant (Table 2). The combination of IW/CPE of 1.0 up to panicle initiation stage and thereafter IW/CPE of 1.2 up to dough stage (I_5) 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) significantly produced higher number of panicles hill^{-1} (10.7), grain yield of 5419 kg·ha^{-1} and straw yield of 6906 kg·ha^{-1}. However, IW/CPE 1.0 throughout the growth stage along with application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS (I_4N_6) recorded higher water use efficiency of 8.4 kg·ha^{-1}·mm^{-1}. This was due to the combined effect of soil moisture availability, nitrogen availability and enhanced uptake of nutrients throughout the growth period as reported earlier by Mandal *et al.* [12] and Reddy *et al.* [27].

Table 1. Influence of irrigation scheduling and nitrogen levels with split application on yield attributes, yield and water use efficiency of aerobic rice.

Treatments	Number of panicles hill^{-1}	Number of filled grains panicle^{-1}	Test weight (g)	Grain yield (kg·ha^{-1})	Straw yield (kg·ha^{-1})	Water Use Efficiency (kg·ha^{-1}·mm^{-1})
			Irrigation Scheduling			
I_1	6.6	77.6	14.0	3405	4665	5.8
I_2	7.3	81.2	14.4	3678	5256	5.8
I_3	8.0	82.9	14.9	3906	5459	6.2
I_4	8.7	84.8	15.1	4278	5745	6.8
I_5	9.1	87.9	15.3	4462	5977	6.5
S.Ed.	**0.16**	**1.57**	**0.33**	**70**	**91**	*
C.D. (0.05)	**0.37**	**3.62**	**0.77**	**161**	**211**	*
			Nitrogen Management			
N_1	6.7	76.8	14.1	3238	4705	5.1
N_2	7.3	78.8	14.4	3583	5014	5.7
N_3	7.7	81.0	14.6	3735	5203	5.9
N_4	8.5	86.8	15.1	4288	5754	6.7
N_5	8.2	83.1	15.0	4085	5589	6.4
N_6	9.3	90.5	15.4	4746	6258	7.5
S.Ed.	**0.15**	**1.68**	**0.36**	**76**	**102**	*
C.D. (0.05)	**0.32**	**3.66**	**0.79**	**152**	**221**	*

*Data not statistically analyzed.

Table 2. Interaction (I x N) effects of irrigation scheduling and nitrogen levels with split application on yield attributes, yield and water use efficiency of aerobic rice.

Treatments	Number of panicles hill^{-1}	Number of filled grains panicle^{-1}	Test weight (g)	Grain yield (kg·ha^{-1})	Straw yield (kg·ha^{-1})	Water Use Efficiency (kg·ha^{-1}·mm^{-1})
I_1N_1	5.8	72.3	13.4	2873	4028	4.9
I_1N_2	6.3	73.7	13.5	3243	4296	5.6
I_1N_3	6.5	75.5	13.9	3321	4475	5.7
I_1N_4	7.0	80.6	14.4	3624	4904	6.2
I_1N_5	6.9	79.1	14.2	3443	4795	5.9
I_1N_6	7.2	84.3	14.8	3925	5490	6.7
I_2N_1	6.1	75.7	13.8	3162	4637	5.0
I_2N_2	6.7	77.4	14.1	3437	4922	5.4
I_2N_3	7.1	79.8	14.3	3591	5137	5.7
I_2N_4	8.0	85.5	14.8	3891	5569	6.2
I_2N_5	7.0	81.0	14.4	3690	5372	5.8
I_2N_6	8.7	87.6	15.2	4300	5898	6.8
I_3N_1	6.6	76.4	14.1	3207	4785	5.1
I_3N_2	7.1	79.8	14.5	3589	5116	5.7
I_3N_3	7.8	81.5	14.8	3725	5229	5.9
I_3N_4	8.5	86.3	15.4	4196	5724	6.6
I_3N_5	8.6	82.8	15.1	3926	5688	6.2
I_3N_6	9.5	90.5	15.6	4792	6213	7.6
I_4N_1	7.3	78.6	14.4	3401	4970	5.4
I_4N_2	8.0	80.0	14.6	3705	5268	5.9
I_4N_3	8.5	83.1	15.2	3956	5346	6.3
I_4N_4	9.3	89.3	15.6	4757	6213	7.5
I_4N_5	9.0	84.0	15.3	4553	5892	7.2
I_4N_6	10.3	93.8	15.7	5296	6783	8.4
I_5N_1	7.8	81.2	14.6	3550	5106	5.2
I_5N_2	8.3	83.0	15.1	3941	5470	5.7
I_5N_3	8.6	85.3	15.0	4080	5827	5.9
I_5N_4	9.9	92.5	15.2	4971	6359	7.2
I_5N_5	9.4	88.7	15.8	4812	6197	7.0
I_5N_6	10.7	96.4	15.9	5419	6906	7.9
S.Ed.	**0.34**	**3.82**	**0.82**	**170**	**231**	*
C.D. (0.05)	**0.70**	**NS**	**NS**	**349**	**477**	*

*Data not statistically analyzed.

4. Conclusion

From the present investigation, it can be concluded that 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 was found to be the better practice for obtaining higher yield attribute and yield. Irrigation at IW/CPE 1.0 throughout the growth stage along with application of nitrogen at 150 kg·ha^{-1} in 5 equal splits at 20, 35, 50, 65 and 80 DAS was recorded the highest water use efficiency in aerobic rice. Hence, it can be adopted as a better management practices for water scarce areas instead of continuous flooding.

5. Future Thrust

Research is needed for screening of drought tolerant cultivars with high yielding characters and appropriate weed management practices for aerobic culture. Also studies are required for developing a new ideotype for aerobic rice with better root characters to survive under moisture stress condition.

Conflicts of Interest

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

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