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Response of aerobic rice to irrigation and nitrogen management in red and lateritic soil of West Bengal

S. DUARY AND K. PRAMANIK

Department of Agronomy
Institute of Agriculture, Visva-Bharati, Sriniketan-731236, West Bengal

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ABSTRACT

Field experiment was conducted during Pre-kharif season of 2016 at Agricultural college farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, Birbhum to study 'Response of aerobic rice to irrigation and nitrogen management in red and lateritic soil'. Observation yield attributing character were recorded.The treatments consist of three water management i.e.I_{75}=Irrigation at 75% of CPE, I_{100}= irrigation at 100% of CPE and I_{125}= irrigation at 125% of CPE at mainplot whereas four levels of nitrogen i.e.N_1= 100% N through fertilizer, N_2= 75 % N through fertilizer + 2.5 t ha^{-1} vermicompost, N_3= 50 % N through fertilizer + 5.0 t ha^{-1} vermicompost and N_4= 25 % N through fertilizer +7.5 t ha^{-1} vermicompostin the sub plots. Irrigation and nitrogen management significantly affected filled grains panicle^{-1}, grain yield, straw yield,1000 grain weight and harvest index.The highest number of filled grains panicle^{-1} (110) as recorded in I_{125} with application of N_1. The highest grain yield of 3935 kg ha^{-1} was recorded from crop receiving I_{125} with N_1 nitrogen treatment. Irrigation at I_{125} with application of N_2 recorded higher (22g) test weight. The highest values were recorded with nitrogen at 100% N through fertilizer and 75 % N through fertilizer + 2.5 t ha^{-1} vermicompost and significantly greater than what obtained from other nitrogen treatment and irrigation management at 100% of CPE and 125% CPE is better over the irrigation at 75% of CPE.

***Keywords* :** Aerobic rice, irrigation, nitrogen and yield

Rice (*Oryza sativa* L.), the staple food of more than half of the population of the world, is an important target to provide food security and livelihoods for millions.Rice provides 30–75 per cent of the total calories to more than 3 billion Asians (Khush, 2004). With 43.39 million hectares, indie ranks number one globally in rice area and with 104.32 million tones stands next only to China in total paddy production in 2015-16 (Anonymous, 2017).

Water is a looming crisis due to competition among agricultural, industrial, environmental and domestic users (Ramana *et al*., 2007). Imminent water crisis, water-demanding nature of traditionally cultivated rice and climbing labour costs ramble the search for alternative management methods to increase water productivity, system sustainability and profitability.The traditional irrigated lowland rice production requires continuous flooding and needs high water inputs.Imminent water crisis, water-demanding nature of traditionally cultivated rice and climbing labour costs ramble the search for alternative management methods to increase water productivity, system sustainability and profitability. A growing scarcity of fresh water will pose problems for rice production in future years, so direct seeded rice or aerobic rice culture is becoming an increasingly popular alternative to transplanting in India and it is cultivated nearly one-third of the total rice area of the country, in spite of many constrains.

Nitrogen is the major and most limiting nutrient to rice growth and yield in almost all environments (Yoshida, 1981); for this reason about one third of the total nitrogen applied to cereal crop is used for rice (Raun and Johnson, 1991). Nitrogen fertilization in rice is expensive throughout the world but nitrogen use efficiency is generally low (30-40 per cent) in traditionally cultivation of rice due to its rapid losses through different pathways such as runoff, volatilization, leaching and denitrification before it is utilized by the rice crop (Bhattacharya and Singh, 1992). So, management of nitrogenous fertilizer plays an important role that affects the rice productivity by maximizing yield attributing characters (Murty *et al.*, 1992 and Nayak *et al*., 2015). Hence the present experiment was initiated to evaluate the irrigation and nitrogen management for enhancing the yield and yield components of aerobic rice.

MATERIALS AND METHODS

A field experiment was conducted in the PSB farm Sriniketan, Birbhum during *Pre-Kharif* season of 2016. The experiment site is located in the western part of West Bengal under sub-humid tropical zone of Eastern India. In this zone generally three main seasons prevailed namely summer or *pre- kharif* (March to June), Rainy or *kharif* (July to October) and winter or *Rabi* (November to February). The geographical location of Sriniketan is about $20^0 39^/$N latitude and $87^0 42^/$E longitude with an average altitude of 58.9 meters above mean sea level.

The soil of experimental field was sandy loam in texture, acidic in reaction (pH 6.1), low in organic carbon (0.49%), and low in available nitrogen (136 kg ha^{-1}), low in available phosphorus (11.5 kg ha^{-1}) and low in

Email:kalipada.pramanik@visva-bharati.ac.in

available potassium (160.5 kg ha^{-1}). The experiment was carried out in Split plot design with irrigation and nitrogen having three replications. The treatments were comprised of three irrigation in main plot *viz*., at 75% of CPE , at 100% of CPE, at 125% of CPE and four nitrogen in sub plot viz., 100% N through Fertilizer (N_1), 75 % N through Fertilizer + 2.5 t ha^{-1} of vermicompost (N_2), 50% N through Fertilizer + 5.0 t ha^{-1} vermicompost (N_3) and 25 % N through Fertilizer +7.5 t ha^{-1} of vermicompost (N_4).

The trial was laid out in split plot design with twelve treatments and each treatment was replicated thrice with the variety *Shbhagi*. The experimental field was initially ploughed with power tiller in order to remove all weeds and other plant residues of previous crop from the field. The second ploughing was done 15 days after first ploughing and light irrigation was applied to the field to enhance the germination of weed seeds and seeds of previous crop. The third ploughing was done three days before sowing to destroy the weeds and previous crops and then levelled with leveller in order to prepare good seed bed for smooth germination of rice seeds. Sowing of seed was done in unpuddled condition on 6th April, 2016 @ 45 kg ha^{-1} in furrows made by trench hoe at 20 cm solid row spacing. Seeds were manually sown (hand dibbled) in 2-3 cm depth within row and covered with soil. Thinning and gap filling was done at seedlings 20 days after sowing (DAS) so as to maintain optimum and uniform plant population in all the plots.Recommended dose of phosphorus and potash fertilizer were applied @ 50 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} by using fertilizers like single super phosphate and muriate of potash, respectively. Vermicompost was applied at final land preparation according to treatment. Full dose of phosphorus and half dose of potash as basal were applied in the rows about 4-5 cm deep before seeding and remaining half dose of the potash was top dressed at 60 DAS. The nitrogen in the form of urea was top dressed in three splits *i.e*.; half dose of nitrogen at 20 DAS and remaining half dose of nitrogen was applied in two equal split each at 40 DAS and 60 DAS.

Irrigation water of 3 cm was applied to all plots for uniform germination thereafter irrigations were given as per treatment details.The volume of irrigation water in each plot was calculated by multiplying the USWB Open Pan Class A evaporimeter reading and area of the plot. The irrigation water was measured through 90^{0}V-notch weirs set up in the pucca channel of the experimental field.

The rate of discharge was calculated as per the formula given below:

$$Q= 0.0138 \times H^{5/2}$$

where, Q is the rate of discharge (litre per second) and H is the head of the crest (cm). The time of irrigation for every plot was computed by using given depth of irrigation, area of the plot and discharge rate. It was calculated by the formula given below

$$T=A*D/Q$$

Where, Q is the rate of discharge (litre per second), A is the area of the plot (m^2), D is the CPE value (mm) and T is the time of irrigation (sec or min).

I_{100}: Irrigation at 100 % of CPE means quantity of irrigation water to be applied equal to what amount of water actually evaporated (measured from USWB Open Pan Class A Evaporimeter) during the irrigation interval and the time of irrigation is decided by visible symptom i.e initiation of rolling of tip of first top leaves (Parthasarathi*et al.*, 2012).

I_{75}: 75 per cent of I_{100}

I_{125}: 125 per cent of I_{100}

Plant height of rice was measured at 60 DAS from the base of the plant at ground surface to the tip of the longest leaf using a standard meter scale and was expressed in cm. For aerial dry matter accumulation, the samples were taken above ground plant parts form 15 cm row length from second row in each plot at 60 DAS. These samples were dried in oven at a temperature of 65-70°C till constant weights were obtained. Average weight was calculated and expressed as dry matter accumulation in g m^{-2}. The number of tillers and panicles were counted from one m^2 area selected randomly and mean value was computed. Again ten panicles were selected randomly for counting of filled grains. A seed counter was used for counting of 1000-grains of hybrid rice and their weight was measured with electronic balance. Harvesting was done manually with sickles after leaving the border area. Net plots were demarcated at first from the portion of the plot kept for recording grain yield. Plants from the demarcated net plot area were harvested, tied in bundles and taken to the threshing floor for drying and threshing. The harvested plants were dried for 3–4 days to bring down the moisture content to around 14 per cent. The weight of the harvested plants after sun drying and before threshing was recorded. After threshing, the seeds were cleaned and sundried and their weight was recorded. The yields in kg plot^{-1}were converted to kg ha^{-1}. Harvest index was calculated using the formula as under:

$$\text{Harvest index } (\%) = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Biological yield(kg ha}^{-1})} \times 100$$

The experimental data recorded for various parameters under study were subjected to statistically analysed ANOVA given by Gomez and Gomez (1984) to draw a valid conclusion. The variation in the treatments mean was tested by using critical difference (CD) values at 5% level of significance.

RESULTS AND DISCUSSION

Plant height

Plant height is one of the important growth parameters of any crop plant which influenced the yield contributing characters. The maximum plant height (50.9 cm) was recorded at I_{100} and it was at par with irrigation at 125% of CPE (I_{125}) but these are significantly higher than irrigation at 75% of CPE (I_{75}). The reduction in plant height at 75% of CPE (I_{75}) irrigationcouldbe due to decline in cell turgor that causes reduction in cell enlargement. Application of 100% N through fertilizer recorded significantly higher plant height than 75 % N through fertilizer + 2.5 t ha^{-1} vermicompost (N_2) but N_2 was at par with the treatment 50 % N through fertilizer + 5.0 t ha^{-1} of vermicompost (N_3).The increase in plant height with increase in nitrogen levels might be due to increase the cell division and cell elongation of the plant.These results are also in agreement with Halder *et al.*(2008) and Uddin *et al.*(2013).

Tillering

Tillering plays a vital role in determining rice grain yield since it is closely related to number of panicles per unit ground area. The maximum number of tillers was recorded at I_{125} and it was at par with I_{100} and I_{100} was recorded significantly higher than I_{75}. I_{100} and I_{125} recorded higher number of tillers that might be due to good crop and root growth throughout growth stages which ultimately increased tiller density (Uphoff, 2001). On the other hand, lower number of tiller under I_{75} might be due to non-availability of water resulted in reduction in the amount of intercepted photosynthetically active radiation tends to reduced tillering (Sokoto and Muhammad, 2014). 100 % N through fertilizer (N_1) and 75 % N through fertilizer + 2.5 t of vermicompost ha^{-1}(N_2) were recorded higher number (410) of tillers over 25 % N through Fertilizer +7.5 t ha^{-1} of vermicompost (N_4). The increase number of tillers m^{-2} with increase in nitrogen management might be due to availability of higher amount of nitrogen which encourage and improve the plant growth and accelerate the cell division which reflected the increase in number of tillers m^{-2}.

Table 1: Effect of irrigation and nitrogen management on growth attributing characters at 60 DAS

Treatments	Plant height (cm)	Number of tiller m^{-2}	Aerial dry mater accumulation(g m^{-2})	LAI
Irrigation management				
I_{75}	47.7	367	430	2.96
I_{100}	50.9	412	549	3.58
I_{125}	50.4	420	626	3.63
SEm (±)	**0.57**	**5.88**	**11.6**	**0.05**
LSD (0.05)	**2.25**	**23.06**	**45.7**	**0.21**
Nitrogen management				
N_1	51.8	439	589	3.73
N_2	50.0	410	567	3.55
N_3	49.0	391	493	3.29
N_4	47.6	359	490	2.98
SEm (±)	**0.58**	**5.9**	**15.1**	**0.07**
LSD (0.05)	**1.71**	**17.53**	**44.8**	**0.2**

Aerial dry matter production

Irrigation at 100% of CPE and at 125% of CPE recorded higher dry matter accumulationof 549 and 626 g m^{-2}, respectively (Table 1). It might be due to effective uptake of water and nutrients with increase in amount of irrigation resulting in increasing the growth of plants. Lower dry matter (430 g m^{-2}) might be due to lower production of tillering and plant height with irrigation at 75% of CPE.Application of 100 % N through fertilizer (N_1) and 75 % N through fertilizer + 2.5 t of vermicompost ha^{-1}(N_2) were recorded higher dry matter production. Increases dry matter with increasing N doses might be to increases the photosynthetic efficiency of crop leading to sink. The higher nitrogen management might have helped in inducing vegetative growth leading to better interception of photo synthetically active radiation and greater photosynthesis by the crop. The increase in nitrogen level improved the dry matter accumulation of the shoot has been reported by Pradhan *et al.*(2014).

Leaf area index

The result showed that irrigation at I_{100} and I_{125} recorded higher LAI over irrigation at I_{75}. The increase in leaf area index under I_{100} and I_{125} could be due to improve the uptake of nutrients under higher moisture condition resulting in more number of leaf and higher leaf area coupled with more number of tillers. The result is in conformity with the finding of Ramamoorthy *et al.*(1998) and Maheswari *et al*. (2008). Regarding leaf area index there was no significant difference between the N_1(100 % through fertilizer) and N_2 (75 % N through fertilizer + 2.5 t ha^{-1} of vermicompost treatment) but N_2 was significantly superior to the rest of the treatment N_3 (50 % N through fertilizer + 5.0 t ha^{-1} of vermicompost). The increase in leaf area index with increase in nitrogen levels might be due to increase in number of leaf and leaf development and also remaining functional over long period. The results are in conformity with the findings of Salem *et al.*(2011) and Nayak (2015).

Number of effective tiller m^{-2}

The maximum number of effective tillers per m^2 (311) was recorded with irrigation management I_{125} and there was no significance difference between I_{125} and I_{100}.The highest number of effective tillers per m^2 (309) was recorded at N_1 (100% N through inorganic fertilizer) which was at par with N_2 (75 % N through fertilizer + 2.5 t ha^{-1} of vermicompost). The lower number of tiller under I_{75} might be due to non-availability of water resulted in reduction in the amount of intercepted photosynthetically active radiation tends to reduced tillering (Sokoto and Muhammad, 2014).

Panicle length

The maximum panicle length was recorded (23 cm) with I_{125} but there was no significant difference between I_{100} and I_{125} whereas I_{100} was recorded significantly higher panicle length than I_{75}. The results also revealed that nitrogen management played an important role for increasing panicle length in aerobic rice. The highest panicle length was recorded at N_1 (100% N through inorganic fertilizer) which was at par with N_2 (75 % N through fertilizer + 2.5 t ha^{-1} of vermicompost). Panicle length increased with the increase of nitrogen fertilization because of nitrogen takes part in panicle formation as well as panicle elongation.

Table 2: Effect of irrigation and nitrogen management on yield attributing characters

Treatments	Number of effective tiller m^{-2}	Panicle length (cm)	Number of filled grain $panicle^{-1}$	Test weight (g)
Irrigation management				
I_{75}	259	19.78	89.6	19.87
I_{100}	294	23.10	98.7	20.83
I_{125}	311	23.11	103	20.72
SEm (±)	**4.62**	**0.3**	**1.49**	**0.33**
LSD (0.05)	**18.13**	**1.16**	**5.84**	**NS**
Nitrogen management				
N_1 309	23.06	104	21.23	
N_2 303	22.54	104	20.82	
N_3 286	21.64	95	20.58	
N_4 254	20.73	85.7	19.27	
SEm (±)	**4.73**	**0.27**	**1.38**	**0.36**
LSD (0.05)	**14.06**	**0.79**	**4.11**	**1.08**

Number of filled grains $panicle^{-1}$

The highest number of filled grains $panicle^{-1}$ was recorded with I_{125}. Irrigation at I_{100} and I_{125} maintained high moisture regimes which increased in number of filled grains $panicle^{-1}$. This might has enhanced the supply of photosynthates from source to sink. The present findings are in close association with Shekara and Sharanappa (2010); Murthy and Reddy (2013). The highest number of filled grains $panicle^{-1}$was recorded at N_1(100% N through fertilizers) but N_1 was at par with N_2. The higher number of filled grains $panicle^{-1}$ might be due to better supply of nitrogen from N_1 (100% N through fertilizers).

Test weight

The average test weight in the experiment ranging from 19 to 21 g irrespective of the different irrigation and nitrogen managements involved (Table 2). Irrigation at I_{100} and I_{125} recordedhigher test weight over $I_{125.}$ This might be due to maintain high moisture regimes which increased in number of filled grains panicle^{-1}. The maximum value of test weight was recorded with N_1 (100% N through inorganic fertilizer) over other nitrogen management during this experiment.

Grain yield

The grain yield recorded in each net plot from different treatments at maturity was analysed statistically and presented in the table 3 irrespective of irrigation and nitrogen managements. The highest grain yield of 3618 kg ha^{-1} was recorded with I_{125} which was at par with I_{100} (3502 kg ha^{-1}). The higher grain yield was recorded with I_{100} and I_{125} might be due to higher growth and yield attributes as well conducive situation for efficient water and nutrients uptake which boost their growth and yield attributes through supply of more photosynthates towards the reproductive sink. This result was in corroborates with the findings of Maheswari *et al.* (2008), Shekara and Sharanappa (2010) and Mandal *et al.* (2013). Reduction of grain yield under irrigation at 75% of CPE could be due to the significant reduction in photo synthetic rate due to inadequate supply of moisture resulting in reduced production of assimilates for growth of panicles and filling of rice grains; ultimately rice yield was drastically decreased. The results are in conformity with the finding of Manna *et al*. (2018).

The maximum value of grain yield of 3740 kg ha^{-1} was recorded with 75 % N through fertilizer + 2.5 t ha^{-1} vermicompost followed by 100% N through fertilizer (3655 kg ha^{-1}), 50 % N through fertilizer + 5.0 t ha^{-1} vermicompost (3426 kg ha^{-1}) and N_4 *i.e.*, 25 % N through fertilizer +7.5 t ha^{-1}(2670 kg ha^{-1}). Significant increase in grain yield could be attributed to the fact that N application improved the N, P and K uptake by crop plant and ultimately accelerate photosynthetic activities resulting in better growth and yield attributes which laid down the foundation for accumulating higher plant dry matter as well as continuous and steady supply of N into the soil solution to meet the required nutrients for physiological processes, which in turn improved the yield. These findings are in close conformity with those of Roy and Mishra (1999), Viraktamath (2006), Seema *et al. (*2014) and Nayak (2015).

Table 3: Effect of irrigation and nitrogen management on grain yield straw yield and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Irrigation management			
$\mathbf{I_{75}}$	2998	4137	0.42
$\mathbf{I_{100}}$	3502	4723	0.43
$\mathbf{I_{125}}$	3618	4888	0.42
SEm (±)	**80**	**84**	**0.01**
LSD (0.05)	**314**	**332**	**NS**
Nitrogen management			
$\mathbf{N_1}$	3655	5092	0.42
$\mathbf{N_2}$	3740	4734	0.44
$\mathbf{N_3}$	3426	4377	0.44
$\mathbf{N_4}$	2670	4127	0.39
SEm (±)	**68**	**136**	**0.01**
LSD (0.05)	**204**	**405**	**0.03**

Straw yield

The highest straw yield was recorded with I_{125} but there was no significance difference between irrigation at 100% of CPE (I_{100}) and 125% of CPE (I_{125}) and also 75% of CPE (I_{75}) and 100% of CPE (I_{100}). The results showed that nitrogen management played an important role for increasing straw yield in aerobic rice. The maximum value straw was recorded with N_1 and there were no significant difference between 75 % N through fertilizer + 2.5 t ha^{-1}and 100% N through fertilizer.This result was in corroborates with the findings of Nayak *et al.* (2015).

Harvest index

Harvest index was estimated from the grain and biological (grain + straw) yields of each plots. All the values were statistically analysed and presented in the table 3.The values of harvest index ranged from 0.39 to 0.44 per cent depending upon irrigation and nitrogen managements during the experiment. However, it was maximum when crop receiving I_{100} and I_{100} was at par with I_{125} and there was no significance difference in harvest index between I_{100} and I_{75}. The maximum harvest was recorded at N_2 and N_3 but there was no significant difference between N_2 and N_1. The similar type of result was also reported by Nayak *et al.* (2015).

From the present investigations, it may be concluded that aerobic rice needs to be irrigated at 100% of CPE, application of nitrogen100% N through inorganic fertilizer for production economically optimum growth attributes, yield attributes, productivity in red and lateritic soils of West Bengal.

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