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Research Article

EFFECT OF NITROGEN LEVEL AND TIME OF APPLICATION ON YIELD AND WATER USE EFFICIENCY OF AEROBIC RICE

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Abstract- Rice is the most important staple food crop. Aerobic rice is a new method of growing rice characterized by direct seeding condition without standing water. Nitrogen nutrition is the major agronomic practice that affects the yield and quality of rice crop. Water use efficiency or water productivity is the ratio of grain yield to total water input was found to be increasing with the increasing levels of nitrogen. Significantly higher water use efficiency was noticed with the application of 125 kg N ha^{-1} (57.59 kg $hacm^{-1}$) followed by application 100 kg N ha^{-1} (53.43 kg $hacm^{-1}$) and significantly superior over 75 kg N ha^{-1} (49.00 kg $hacm^{-1}$). Application of nitrogen in 4 splits (25%N at basal dose + 25% N at tillering + 25% N at PIstage +25%N at PE) resulted in higher water use efficiency (59.32 kg $hacm^{-1}$) followed by 3 splits application (33 % N at basal dose + 33% N at tillering +33 % N at PI stage) (55.71 kg $hacm^{-1}$) and lower water use efficiency was with nitrogen in 2 splits (50 % N at 15 DAE + 50 % N at PI stage) (47.23 kg $hacm^{-1}$).

Keywords- Aerobic rice, Nitrogen levels, Time of application, Yield, Water use efficiency

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Introduction

Rice (*Oryza sativa* L.) is the most important staple food crop in Asia and it occupies the prime place among the food crops after wheat. Human consumption accounts for 85 per cent of total rice production and it deserves a special status among the cereals. Worldwide, rice is being cultivated in an area of 158 million hectare, which is more than 10 per cent of the arable land. In India, rice is cultivated in an area of 42 million hectares with the production of 102 million tonnes, which contributes to 42 per cent of total food grain production of our country. The average productivity of rice in India is 2.4 tonnes ha^{-1} as against 6.10 and 8.30 tonnes ha^{-1} in China and Egypt respectively. In Karnataka, rice is cultivated in 1.3 million hectare with a production of 5.0 million tones and the productivity of 2.7 tonnes ha^{-1} in different agro climatic zones [1].

Aerobic rice is a new method of growing rice characterized by direct seeding condition without standing water. This concept was first developed in China during mid 1980. The term "Aerobic rice" was coined recently by IRRI for high yielding rice grown in non-puddled and non-flooded aerobic soil. It is recent method in rice production that leads to save the good amount of water. Aerobic rice cultivation entails the growing of rice in aerobic soil with the use of external inputs such as supplementary irrigation and fertilizers and aiming at high yield. Yield of aerobic rice varies from 4.5 to 6.5 t ha^{-1}, which is about double that of traditional upland varieties and about 20-30 per cent lower than that of lowland varieties grown under flooded conditions [2]. However, the water use was reported to be about 60 per cent less than that of lowland rice with total water productivity of 1.6 time higher and net returns to water use was two times higher. Aerobic rice is an alternate system that requires less water and high external inputs.

Nitrogen is pivotal in realization of rice yield. In India about 67 per cent of rice soils are estimated to be deficit in nitrogen and consequently rice crop has become a major consumer of nitrogen fertilizer. The use efficiency of applied fertilizer nitrogen by rice crop is very low, ranging from 30 to 50 per cent. Rice consumes about 40 per cent of total fertilizer nitrogen used in India. Nitrogen nutrition is the major agronomic practice that affects the yield and quality of rice crop, it is required at early and mid tillering stages to maximize the growth and yield of crop. It is imperative to effective nitrogen management such as rate and synchronized N application with the crop requirement in real time plays an important role in increasing response to added fertilizers and thereby, improving the grain yield of rice varieties including hybrids.

Materials and methods

The field experiment was conducted at Zonal Agricultural Research Station, Visweshwaraiah Canal Farm (V. C. Farm), Mandya, University of Agricultural Sciences, Bengaluru during *kharif* 2013, which comes under Southern Dry Zone of Karnataka (Zone-VI). The experimental site is situated between 12º 45' N latitude, 76º 45' E longitude and at an altitude of 695 meters above mean sea level (MSL).

Soil sampling and soil characteristics of the experimental field

Composite soil samples were collected from 0-15 cm depth of the soil from experimental area by using screw auger before start of the experiment. The composite soil samples of about 250 g was air dried and passed through a 2.0 mm sieve and used for physical and chemical analysis as per standard procedures.

The experimental soil was red sandy loam in texture with an average particle content of 53.4 per cent coarse sand, 14.8 per cent fine sand, 16.6 per cent silt and 15.2 per cent clay. The soil was neutral in reaction (pH 7.3) organic carbon content was 0.55 per cent with electrical conductivity of 0.023 dSm^{-1}. The soil had medium available nitrogen (250.88 kg ha^{-1}), phosphorus (25.13 kg ha^{-1}) and low in available potassium (170.30 kg ha^{-1}). The actual rainfall received during the crop growth period from July to December 2013 was 418.50 mm as against normal rainfall of 461.05 mm and which 42.50 mm is less than the normal rainfall.

Totally 21 treatment combinations of three main plot treatment of Nitrogen levels and in sub plots seven split application of nitrogen were laid out in split plot design with three replications.

Main plot treatments (3): **Nitrogen levels**

N_1: 75 kg ha^{-1}

N_2: 100 kg ha^{-1}

N_3: 125 kg ha^{-1}

Sub plot treatment (7): Time of application

F_1: 50 % N at basal dose + 50 % N at PI stage.

F_2: 50 % N at 15 DAE + 50 % N at PI stage.

F_3: 33% N at basal dose + 33% N at tillering + 33%N at PI stage.

F_4: 33% N at 15 DAE + 33 % N at tillering + 33%N at PI stage.

F_5: 25% N at basal dose + 25% N at tillering + 25 %N at PI stage +25 % N at PE

F_6: 25%N at 15 DAE + 25% N at tillering + 25 %N at PI stage +25 %N at PE.

F_7: 50 % N at basal dose + 25 % N at tillering + 25 % N at PI stage

(Note: DAE: Days After Emergence PI: Panicle Initiation PE: Panicle Emergence)

The observations on growth parameters like plant height, number of tillers per m^2, number of leaves per plant, leaf area per plant, LAI and dry matter production were recorded at 30, 60, 90 DAS and at harvest. At the time of harvest of crop yield components *viz.,* number of panicles per m^2, panicle weight (g), panicle length (cm), number of grains per spikelet and thousand grain weight (g) were recorded.

Results and Discussion

Yield

Knowledge on association of yield components with yield is a paramount importance in formulating an effective rice cultivation system with water saving and high response to nutrients. The yield components such as number of productive tillers, number of spikelet per panicle, number of filled spikelets $panicle^{-1}$ and 1000 grain weight were higher with increased nitrogen levels. The enhanced values in yield components might be due to higher leaf area and DMP leading to higher photosynthetic rate and accumulation of more assimilates which led to increased sink size. The results of the present investigation are in conformation with the findings of Chopra *et al*. (2003) and Yadav *et al.* (2010 [3,9]).

The data on grain yield (kg ha^{-1}) of aerobic rice varied significantly due to nitrogen levels and times of application are presented in [Table-1] Significantly higher grain yield was observed with the application of 125 kg N ha^{-1} (6498.53kg ha^{-1}) followed by application of 100 kg N ha^{-1} (6048.28 kg ha^{-1}) than application of 75 kg N ha^{-1} (5528.61 kg ha^{-1}). Among different times of application of nitrogen, nitrogen in 4 splits (25%N at basal dose + 25% N at tillering + 25% N at PIstage +25%N at PE) produced significantly higher grain yield (6693.83 kg ha^{-1}) and which was on par with the application of nitrogen in 3 splits (33 % N at basal dose + 33 % N at tillering + 33 % N at PI stage) (6285.80 kg ha^{-1}) followed by application of nitrogen in 3 splits (50 % N at basal dose + 25 % N at tillering + 25 % N at PI stage) (6198.89 kg ha^{-1}) compared to application of nitrogen in 2 splits (50 % N at 15 DAE + 50 % N at PI stage) (5329.37 kg ha^{-1}). The interaction between nitrogen levels and times of applications was not found significant.

Significantly higher straw yield of aerobic rice was observed with the application of 125 kg N ha^{-1} (7689.50 kg ha^{-1}) followed by application of 100 kg N ha^{-1} (7232.49 kg ha^{-1}) but superior over the application of 75 kg N ha^{-1} (6198.49 kg ha^{-1}). With respect to different times of application of nitrogen, nitrogen in 4 splits (25%N at basal dose + 25% N at tillering + 25% N at PIstage +25%N at PE) resulted in higher straw yield (7540.48 kg ha^{-1}) and which was on par with the application of nitrogen in 3 splits (33 % N at basal dose + 33 % N at tillering + 33 % N at PI stage and 50 % N at basal dose + 25 % N at tillering + 25 % N at PI stage, 7347.70 and 7291.85 kg ha^{-1}, respectively). However, lower straw yield (6842.49 kg ha^{-1}) was observed with application of nitrogen in 2 splits (50 % N at 15 DAE + 50 % N at PI stage). The interaction effect between nitrogen levels and times of application was not found significant [Table-1]

Harvest index of aerobic rice did not differed significantly due to nitrogen levels and times of application [Table-1] However, higher harvest index was observed with the application of 75 kg N ha^{-1} (0.47) and lower harvest index was observed with the application of nitrogen 100 and 125 kg N ha^{-1} (0.46). Among different times of application of nitrogen, higher harvest index of aerobic rice was observed with nitrogen in 4 splits (0.48) and lower harvest index was recorded with application of nitrogen in 2 splits (0.44).

The improvement in yield components under 125 kg N ha^{-1} might be due to good vegetative growth, higher leaf area and DMP. Increase in filled grain and thousand-grain weight with increased nitrogen levels might be due to nitrogen induced enhancement of photosynthetic activity and these resulted in the translocation of photosynthates and amino acids from the leaves and culms to the grain. It is in accordance with findings of Belder*et al.* (2005).

Improvement in yield components might be due to N application during panicle to flowering increases the number of filled spikelets, $panicle^{-1}$ and nitrogen absorbed after flowering tends to increase thousand grain weight. Application of nitrogen coincides with flowering stage resulted in improvement of single seed weight and reduction in spikelets sterility and NUE and recovery fraction of applied nitrogen with more splits. Application of nitrogen to match the crop demand at different physiological stages and reduced losses reflected in recording the higher grain and straw yield and NUE and recovery fraction of applied N due to the minimum loss of N through leaching.

Grain, Straw yield and yield attributes were significantly influenced by time of nitrogen application. Significantly, higher grain and straw yield was obtained with application of nitrogen in 4 splits compared to nitrogen in 3 and 2 splits. Thus could be attributed due to the minimum loss of N through leaching and efficient N-utilization by crop resulting in better vegetative growth and production of more filled spikelets, panicle weight and panicle length [4]**.**

There was an increase in grain yield due to increase in N-levels. The higher grain yield was obtained with 125 kg N ha^{-1} (6499 kg ha^{-1}) and which was on par with the application of 100 kg N ha^{-1} (6029 kg ha^{-1}) than application of 75 kg N ha^{-1} (5529 kg ha^{-1}). Similar trend was observed with straw yield. These results are in conformity with those of Malla Reddy *et al.* (2012) [5]. Higher yield might be due to improved root growth, increased tillering, water use efficiency and energy use efficiency. Higher leaf area and duration which are responsible for the higher photosynthetic activity and which promoted the dry matter production resulting in higher grain and straw yield.

Water Use Efficiency

Water use efficiency (WUE) is the measure of a cropping system's capacity to convert water into plant biomass or grain. It includes both the use of water stored in the soil and rainfall during the growing season.

Rice is the major consumer of irrigated water, particularly in the dry season. Lack of rainfall makes cropping impossible without irrigation. Irrigated rice has very low water-use efficiency as it consumes 3000–5000 liters of water to produce 1 kg of rice. The traditional rice production system not only leads to wastage but also causes environmental degradation and reduces fertilizer use efficiency. Along with high water requirement, the traditional system of transplanted rice production in puddled soil on long run leads to destruction of soil aggregates and reduction in macro pore volumes, and to a large increase in micro pore space which subsequently reduce the yields of post rice crops.

Water use efficiency or water productivity is the ratio of grain yield to total water input was found to be increasing with the increasing levels of nitrogen. Significantly higher water use efficiency was noticed with the application of 125 kg N ha^{-1} (57.59 kg $hacm^{-1}$) followed by application 100 kg N ha^{-1} (53.43 kg $hacm^{-1}$) and significantly superior over 75 kg N ha^{-1} (49.00 kg $hacm^{-1}$). These results are in findings of Pasha *et al*. (2013) [7]. Application of nitrogen in 4 splits (25%N at basal

Table-1 *Grain yield, straw yield and harvest index of aerobic rice as influenced by nitrogen levels and times of application*

Treatments	Yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Main plot:Nitrogen levels			
N_1=75 kg ha^{-1}	5528.61	6198.49	0.47
N_2=100 kg ha^{-1}	6048.28	7232.49	0.46
N_3=125 kg ha^{-1}	6498.53	7689.50	0.46
S.Em±	152.79	126.62	0.00
CD ($p \leq 0.05$)	460.68	381.77	NS
Subplot: Time of application			
F_1=50 % N at Basal dose + 50 % N at PI stage.	5431.57	6537.37	0.45
F_2=50 % N at 15 DAE + 50 % N at PI stage.	5329.37	6842.49	0.44
F_3=33 % N at basal dose + 33% N at tillering +33 %N at PI stage.	6285.80	7347.70	0.46
F_4=33 %N at 15 DAE + 33 % N at tillering +33 % N at PI stage.	6094.13	7065.53	0.46
F_5=25%N at basal dose + 25% N at tillering + 25% N at PIstage +25%N at PE	6693.83	7540.48	0.47
F_6=25 % N at 15 DAE + 25 % N at tillering + 25 % N at PI stage + 25 % N at PE.	6095.71	6655.70	0.48
F_7=50 % N at basal dose + 25 % N at tillering + 25 % N at PI stage	6198.89	7291.85	0.47
S.Em±	155.46	241.70	0.01
CD ($p \leq 0.05$)	430.91	669.96	0.01
Interaction (NXF)			
S.Em±	252.47	379.57	0.01
CD ($p \leq 0.05$)	NS	NS	NS

DAE-Days after emergence DAS-Days after sowing PI-Panicle initiation PE- Panicle emergence NS- Non Significant.

Table-2 *Water use efficiency (kg $hacm^{-1}$) of aerobic rice as influenced by nitrogen levels and time of application*

Treatments	Irrigation water applied /plot ($9m^2$)(liter)	Number of irrigations	Total water applied /plot (liters)	Irrigation water applied (cm ha^{-1})	Rainfall (mm ha^{-1})	Total water applied (cm ha^{-1})	Yield (kg ha^{-1})	Water productivity (kg $hacm^{-1}$)
Main plot : Nitrogen levels								
N_1	516.43	13.00	6713.57	74.60	38.23	112.83	5528.61	49.00
N_2	516.43	13.00	6713.57	74.60	38.23	112.83	6028.28	53.43
N_3	516.43	13.00	6713.57	74.60	38.23	112.83	6498.53	57.59
S.Em±	-	-	-	-	-	-	152.79	1.35
CD ($p \leq 0.05$)	-	-	-	-	-	-	460.68	4.08
Sub plot : Time of application								
F_1	516.43	13.00	6713.57	74.60	38.23	112.83	5431.57	48.14
F_2	516.43	13.00	6713.57	74.60	38.23	112.83	5329.37	47.23
F_3	516.43	13.00	6713.57	74.60	38.23	112.83	6285.80	55.71
F_4	516.43	13.00	6713.57	74.60	38.23	112.83	6094.13	54.01
F_5	516.43	13.00	6713.57	74.60	38.23	112.83	6693.83	59.32
F_6	516.43	13.00	6713.57	74.60	38.23	112.83	6095.71	54.02
F_7	516.43	13.00	6713.57	74.60	38.23	112.83	6198.89	54.94
S.Em±	-	-	-	-	-	-	155.46	1.37
CD ($p \leq 0.05$)	-	-	-	-	-	-	430.91	3.81
Interaction (NXF)								
S.Em±	-	-	-	-	-	-	252.47	2.23
CD ($p \leq 0.05$)	-	-	-	-	-	-	NS	NS

dose + 25% N at tillering + 25% N at PIstage +25%N at PE) resulted in higher water use efficiency (59.32 kg hacm^{-1}) followed by 3 splits application (33 % N at basal dose + 33% N at tillering +33 % N at PI stage) (55.71 kg hacm^{-1}) and lower water use efficiency was with nitrogen in 2 splits (50 % N at 15 DAE + 50 % N at PI stage) (47.23 kg hacm^{-1}). These results are also in accordance with the findings of Sathiya and Ramesh (2009) [8].

Conclusion

The application of 125 kg of nitrogen under 4 splits (25%N at basal dose + 25% N at tillering + 25% N at PIstage +25%N at PE) has given higher grain yield, straw yield, harvest index and water use efficiency. So higher water use efficiency of aerobic rice system due to lower water requirement and higher grain yield.

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Compliance With Ethical Standards:

Conflict of interest: The authors declare that they have no conflict of interest.

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