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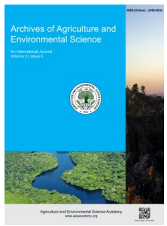

ORIGINAL RESEARCH ARTICLE

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Nitrogen uptake and economics of black rice (*Oryza sativa* L. indica) under different crop geometries and nitrogen management practices

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ABSTRACT

Black rice has more antioxidants than any other rice variety. It is considered to have multiple benefits in human health due to the presence of different antioxidants. A field experiment was conducted during rainy season of 2015-2016 to assess the nitrogen uptake, use efficiency and economics of black rice production under different crop geometry and nitrogen (N) management practices in Rampur, Chitwan, Nepal. The experiment was laid out in strip plot design with three replications. The experiment consisted of treatment combination of three crop geometry (20 cm × 20 cm, 20 cm × 15 cm and 15 cm × 15 cm) in vertical plots and three nitrogen management practices (N level: 30 kg N ha^{-1}, 60 kg N ha^{-1}, and LCC based N-management) in horizontal plots. The results showed that the highest N uptake was recorded from closer spacing (15 cm × 15 cm) with LCC based N management. The net return and B: C ratios were higher at a closer spacing of 15 cm × 15 cm with LCC based N management and closer spacing of 15 cm × 15 cm with N application of 60 kg ha^{-1}. The overall analysis revealed that LCC based N management under closer crop geometry (15 cm × 15 cm) was the best management practices because of high nitrogen uptake and highest monetary return with B: C ratio of 5.76.

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INTRODUCTION

Black or pigment rice is rice of high demand. The popularity of this rice is due to its health benefit, high demand among urban societies and high market value. The antioxidant property of rice is due to anthocyanin content and it is also rich in fiber, several minerals like Fe, Mn, Cu, etc. (Kushwaha, 2016). The accumulation of anthocyanin in different layer of the pericarp and aleuronic region makes rice black or deep purple in color (Chaudhary, 2003). Nitrogen is one of the most important essential nutrients for growth of plant as it is important component of RNA, DNA, amino acids, nucleic acids, nucleotides, chlorophyll, enzymes, and hormones. The chlorophyll present in the leaves determines the ability of crop to utilize solar radiation, which depends upon uptake of nitrogen from soil (Peng *et al.*, 1955). Crop geometry is an arrangement of the plant in different rows and column in an area. It is an important factor for optimizing spacing between plants for efficient utilization of the natural resources like light, water, nutrient and space (Haque *et al.*, 2012). Crop geometry in plant varied according to genetic characteristics of the plant (size of the plant, elasticity of the plant, foraging area or soil cover dry matter partitioning and crop and variety), time of sowing, environmental factors, and fertilizer application.

There is limited information on N uptake and use efficiency by black rice grown under different N management practices. Mineral uptake is the process in which minerals enter the cellular mineral through plant roots, typically following the same pathway of water. Plants absorb minerals in ionic form: nitrogen enters as nitrate (NH_4^+) or ammonium ion (NO_3^-).

A large portion of applied nitrogen losses from flooded rice field which contribute to the low N use efficiency of rice as compared to another crop. Rakshit *et al.* (2014) reported that an average N recovery efficiency for fields managed by farmers ranging from 20 to 30% under rainfed conditions and 30-40% under irrigated conditions. Major driving processes responsible for these heavy losses from rice field are Volatilization, nitrification, denitrification, and leaching (Aulakh and Singh, 1996). Nitrogen Use Efficiency (NUE) is a term used to indicate the ratio between the amount of fertilizer N removed from the field by the crop and the amount of fertilizer N applied. Khadka (2016) performed experiment in response of Black rice to different dose of nitrogen and found that black rice *var.*G60 is very low response to nitrogen. A field experiment was conducted with objectives to known the nitrogen uptake, use efficiencies and economics of black since rice is not only a source of food, it is also a major employer and source of income for people.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Farm of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal during July to December 2015-2016. The soil of the experimental field was silty loam in texture and acidic in reaction (pH 5.71) with low organic matter content (2.47 %). The total nitrogen, available phosphorus and exchangeable potassium were 0.12%, 35.22 kg ha^{-1}, 57.77 kg ha^{-1} soil. The total rainfall during the crop season was 1707.6 mm and the relative humidity ranged from 75.0% in June and 89.7% in October. The mean Maximum temperature during the experimental period ranged from 30.84°C to 35.18°C.

The experiment was laid out in strip plot design with two factors with three replications. The horizontal factor consisted of three crop geometry (20 cm × 20 cm, 20 cm × 15 cm, and 15 cm ×15 cm) and vertical factor consisted of three nitrogen management practices (30 kg N ha^{-1}, 60 kg N ha^{-1}, and LCC based N application). The plot size was 3m × 4.2 m. Black rice (var. G 60) seedlings were raised in well prepared dry seed bed. Rice seed was sown on June 8, 2016 with the seed rate of 50 kg ha^{-1}. The nursery bed was fertilized through using Urea and SSP with 2.25 g m^{-2} and 50 g m^{-2}, respectively and mulched using wheat straw. Frequent irrigation through hand watering jar was given to recover the seedling from drought. Twenty six old seedlings were uprooted carefully from the nursery and transplanted (2-3 seedlings/hill) on the well puddled experimental plots on with three crop geometry as treatments. Full dose of phosphorous, potash and 25 kg ha^{-1} $ZnSO_4$ were applied as basal dose. Basal doses of nitrogen were applied in 30 kg ha^{-1}and 60 kg ha^{-1}nitrogen treatment @ 30 kg ha^{-1}. Remaining nitrogen dose of treatment 60 kg ha^{-1}was applied during active tillering stage after first hand weeding. In LCC no nitrogen was applied as basal dose. First reading of LCC was done at 15 DAT the value of LCC was found below critical (< 4) and 30 kg ha^{-1}nitrogen was applied at a time. Similarly 2nd split of nitrogen using LCC was applied at 36 DAT which was 3rd reading of LCC. The crop of individual plots was separately harvested at full maturity. Data on nitrogen content of grain and straw was obtained by adopting Kjeldahl method and benefit cost ratio was calculated after taking data of biological yield. The price rate of rice grain was NRs. 250/ kg and rice straw was NRs. 3.25 /kg. Total N uptake was determined by the formula adopted by Sikdar *et al.* (2008). Data analysis was done with Microsoft Excel ver. 2016 and R-program. Data were subjected to analysis of variance (ANOVA) tests. When significant differences were found, means were separated and assessed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effect of crop geometry and nitrogen management

Nitrogen uptake and use efficiency

Grain nitrogen uptake, Straw nitrogen uptake and total nitrogen uptake was found non-significant under different crop geometry and nitrogen management practices (Table 1). Grain nitrogen uptake and total nitrogen uptake was significantly influenced where as straw nitrogen uptake was found non-significant under different nitrogen management practices (Table 1). Higher total nitrogen uptake in 60 kg ha^{-1} and LCC might be due to higher uptake of nitrogen with higher availability. Similarly, total nitrogen uptake in LCC based nitrogen management is relatively higher than nitrogen applied at the rate of 60 kg ha^{-1}this might be due to fewer loss results more uptake of applied nitrogen. Similar result was found by (Bhat *et al.*, 2017) and (Kumar *et al.*, 2010)

Partial factor productivity of applied Nitrogen (PFP-N), Nitrogen Efficiency Ratio (NER), and Internal Efficiency (IE) were found non-significant in case of crop geometry (Table 2). Similarly Nitrogen Efficiency Ratio (NER), and Internal Efficiency (IE) was found non-significant in case of nitrogen management practices but Partial factor productivity of applied nitrogen (PFP -N) was significantly influenced and found significantly higher in 30 kg ha^{-1}than others (Table 2). Partial factor productivity is found relatively higher in LCC based N management then same amount (60 kg ha^{-1}) applied adopting splitting this might be due to higher uptake of nutrient in LCC based N management. Decline in partial factor productivity at higher level of N may be due to decline in indigenous soil N supply and low response of black rice to applied N. Khadka (2016) found that black rice *var.*G60 is very low response to nitrogen. Major decline in partial factor productivity for N might be due to nutrient imbalance, decline in indigenous soil N supply, subsoil compaction, reduction of root volume and increased disease and pest incidence (Karim and Ramasamy, 2000).

Economics

The cost of cultivation greatly differed among the crop geometry and nitrogen management practice (Table 3). On an average, the lowest cost of cultivation was found in wider spacing (20 cm × 20 cm) by 10.78% and 14.38% than the spacing (15 cm × 15 cm) and spacing (20 cm × 20 cm) respectively. Cultivation cost was increased as geometry between crop and row decreases,

Table 1. Grain nitrogen uptake, straw nitrogen uptake and total nitrogen uptake as influenced by crop geometry and nitrogen management at Rampur, Chitwan in 2015-16.

Treatment	Nitrogen uptake (kg ha^{-1})		
	Straw nitrogen uptake (SNU) kg ha^{-1}	Grain nitrogen uptake (GNU) kg ha^{-1}	Total nitrogen uptake (TNU) kg ha^{-1}
Horizontal factor: Crop geometry			
20cm × 20cm	25.9	12.22	38.2
20cm ×15cm	33.1	14.46	47.6
15cm × 15cm	35.3	16.58	51.9
LSD (0.05)	NS	Ns	NS
SEm (±)	2.18	1.27	3.11
CV(%)	12.0	15.3	11.7
Vertical factor: Nitrogen management			
30 kg ha^{-1}	28.3	11.86^{b}	40.1^{b}
60 kg ha^{-1}	31.6	15.21^{a}	46.8^{ab}
LCC (60 kg ha^{-1})	34.5	16.20^{a}	50.7^{a}
LSD (0.05)	NS	2.35	6.86
Sem (±)	1.30	0.60	1.75
CV(%)	7.1	7.2	6.6
Grand mean	31.5	14.42	45.9

Treatment means in columns followed by common letters are not significantly different from each other based on DMRT at 5% level of significance.

Table 2. Nitrogen use efficiency of black rice as influenced by crop geometry and nitrogen management at Rampur, Chitwan in 2015-16.

Treatment	Nitrogen use efficiency		
	Partial factor productivity of applied nitrogen (PFP-N)	Nitrogen efficiency ratio (NER)	Internal efficiency (IE)
Horizontal factor: crop geometry			
20 cm × 20 cm	18.34	94.6	21.96
20 cm ×15 cm	19.98	85.0	19.31
15 cm ×15 cm	24.26	89.1	22.71
LSD (0.05)	NS	NS	NS
SEm (±)	1.22	5.37	0.82
CV(%)	10.1	10.4	6.7
Vertical factor: Nitrogen management			
30 kg ha^{-1}	27.75 ^{a}	93.7	21.41
60 kg ha^{-1}	16.38 ^{b}	86.6	20.71
LCC (60 kg ha^{-1})	18.44 ^{b}	88.5	21.87
LSD (0.05)	3.20	NS	NS
SEm (±)	0.82	4.69	0.72
CV(%)	6.8	9.1	5.8
Grand mean	20.86	89.6	21.33

Treatment means in columns followed by common letters are not significantly different from each other based on DMRT at 5% level of significance.

this may be due to more seed requirement, more labor for transplanting and higher requirement of other input. Cultivation cost increases as nitrogen dose increases. When LCC is adopted the cultivation cost was increased this might be due to increased cost for the additional amount of nitrogen and labor for LCC adoption. Gross return and Net return was significantly higher in narrow crop geometry 15 cm × 15 cm than other crop geometry of 20 cm × 15 cm and 20 cm × 20 cm (Table 3). This might be due to higher biological yield from narrow geometry. Mondal *et al.* (2013) also found that high density paid highest gross and net return. B: C ratio was non- significant among treatments but it goes on increasing as space between crops and rows goes on decreasing (Table 3). This may be due to the higher requirement of inputs like labor, seed results in higher input cost in closer geometry. But relatively higher B: C ratio was obtained from narrow crop geometry. Jena *et al.* (2010) found that highest monetary return and highest B:C ratio was from plant spacing 15 cm × 15 cm. Gross return and Net return was significantly higher in LCC based nitrogen management followed by 60 kg Nha^{-1}. Similarly the B: C ratio was significantly different among treatments, it goes on increasing as nitrogen rate goes on increasing and found significantly highest in LCC based nitrogen management than others (Table 3). Satpute *et al.* (2014) and Maiti *et al.* (2004) also favors the use of LCC for nitrogen management in rice as it increases return by decreasing nitrogen use as well as increasing yield of rice as compared to N broadcasting.

Interaction effect of crop geometry and nitrogen management

The interaction effect between crop geometry and Nitrogen management Practices was significant in Grain Nitrogen Uptake. Significantly higher Grain Nitrogen Uptake was obtained from treatment combination closer geometry (15 cm × 15 cm) with LCC based N management (21.21 kg ha^{-1}) (Table 4). Field applied N adopting LCC and closer spacing had higher biological yield. Higher N uptake was obtained when better synchronization of N supply with crop N demand (Dhyani *et al.*, 2017). Similarly, closer crop geometry consists of high density planting resulting higher biomass production and record higher nitrogen uptake (Dhyani *et al.*, 2017).

B: C ratio, Net return and Gross return were significantly influenced by Interaction effect between crop geometry and Nitrogen management Practices (Tables 5-7). Significantly higher Gross return (488.9 thousand ha^{-1}), Net return (404.0 thousand ha^{-1}) and B: C (5.76) ratio was obtained from interaction of Closer geometry (15 cm × 15cm) with LCC based N management. It might be due higher biological yield results higher net return.

Table 3. Cost of cultivation, gross return, net returns, and B: C ratio of black rice as influenced by crop geometry and nitrogen management at Rampur, Chitwan in 2015-16.

Treatments	Total Production cost (NRs.ha^{-1}) (000)	Gross returns (NRs.ha^{-1}) (000)	Net return (NRs.ha^{-1}) (000)	B:C ratio
Horizontal factor: Crop geometry				
20cm × 20cm	74.46	246.02^{b}	171.56^{b}	3.30
20cm × 15cm	79.46	270.25^{b}	190.79^{b}	3.40
15cm × 15cm	83.46	344.01^{a}	260.54^{a}	4.11
LSD (0.05)		69.07	57.769	NS
SEm (±)		14.71	14.71	0.18
C.V(%)		8.9	12.3	8.8
Vertical factor: Nitrogen management				
30 kg ha^{-1}	77.40	245.68^{c}	168.29^{c}	3.17^{c}
60 kg ha^{-1}	79.40	289.28^{b}	209.88^{b}	3.61^{b}
LCC (60 kg ha^{-1})	80.60	325.32^{a}	244.72^{a}	4.02^{a}
LSD (0.05)		37.57	31.47	0.386
SEm (±)		8.016	8.02	0.098
CV(%)		4.8	6.7	4.7
Grand Mean	79.13	286.76	207.63	3.60

Treatment means in columns followed by common letters are not significantly different from each other based on DMRT at 5% level of significance

Table 4. GNU of black rice as influenced by the interaction between crop geometry and N management at Rampur, Chitwan in 2015-16.

Nitrogen management practices	GNU (kg ha^{-1})		
	Crop geometry		
	20cm × 20cm	20cm ×15cm	15cm ×15cm
30 kg ha^{-1}	11.98^{d}	12.68^{cd}	10.06^{d}
60 kg ha^{-1}	9.99^{d}	17.17^{abc}	18.48^{ab}
LCC (60 kg ha^{-1})	14.69^{bcd}	13.53^{cd}	21.21^{a}

Treatment means in columns followed by common letters are not significantly different from each other based on DMRT at 5% level of significance.

Table 5. Net return of black rice as influenced by the interaction between crop geometry and N management at Rampur, Chitwan in 2015-16.

Nitrogen management practices	Net return (NRs. thousand ha^{-1})		
	Crop geometry		
	20cm × 20cm	20cm ×15cm	15cm ×15cm
30 kg ha^{-1}	206.7^{cd}	234.5^{cd}	217.7^{cd}
60 kg ha^{-1}	166.1^{d}	271.4^{bc}	359.7^{ab}
LCC (60 kg ha^{-1})	284.2^{bc}	222.4^{cd}	404.0^{a}

Treatment means in columns followed by common letters are not significantly different from each other based on DMRT at 5% level of significance.

Table 6. Gross return of black rice as influenced by the interaction between crop geometry and N management at Rampur, Chitwan in 2015-16.

Nitrogen management practices	Gross return (NRs. thousand ha^{-1}) Crop geometry		
	20cm × 20cm	20cm ×15cm	15cm ×15cm
30 kg ha^{-1}	279.4^{cd}	315.5^{cd}	299.4^{cd}
60 kg ha^{-1}	240.8^{d}	351.1^{bc}	443.5^{ab}
LCC (60 kg ha^{-1})	360.2^{bc}	300.1^{cd}	488.9^{a}

Treatment means in columns followed by common letters are not significantly different from each other based on DMRT at 5% level of significance.

Table 7. B: C ratio of black rice as influenced by the interaction between crop geometry and N management at Agronomy farm, AFU, Rampur in 2015-16.

Nitrogen management practices	B: C ratio Crop geometry		
	20cm × 20cm	20cm ×15cm	15cm ×15cm
30 kg ha^{-1}	3.84^{cd}	3.90^{cd}	3.66^{cd}
60 kg ha^{-1}	3.22^{d}	4.40^{bcd}	5.27^{ab}
LCC (60 kg ha^{-1})	4.74^{abc}	3.86^{cd}	5.76^{a}

Treatment means in columns followed by common letters are not significantly different from each other based on DMRT at 5% level of significance.

Conclusion

This investigation concluded that black rice is low responsive to applied nitrogen but found relatively higher uptake of nitrogen in LCC based nitrogen management in closer crop geometry (15 cm × 15 cm). Highest monetary return (404.0 thousand ha^{-1}) and highest B: C ratio (5.76) can be obtained from LCC based nitrogen management with closer spacing (15 cm × 15 cm). Therefore Black rice can be grown profitably in closer crop geometry (15 cm×15 cm) with LCC based nitrogen management.

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