



Response of Some Landrace Rice (*Oryza sativa* L.) Cultivars to Applied Nitrogen in Lowland Ecosystem

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Abstract

An experiment was conducted to determine the effects of nitrogen (N) fertilization on growth and yield of some landrace rice (*Oryza sativa* L.) cultivars in lowland ecosystem. Three popular landrace rice cultivars: Rajashail, Kutiagni and Sadamota were treated with five times of N application viz. (i) two split applications of prilled urea (PU) at 10 days after transplanting (DAT) and before panicle initiation (PI) stage, (ii) deep placement of urea super granule (DPUSG) at 10 DAT, (iii) DPUSG before PI stage, (iv) PU application before PI stage and (v) control. The results showed that the landrace rice cultivar Kutiagni had the highest number of tillers under PU, while Rajashail gave the highest number of tillers under DPUSG applied before PI stage. Further, Kutiagni produced higher amount of dry matter under two splits of PU, while Rajashail produced higher amount of dry matter under DPUSG applied before PI stage. However, application of PU before PI stage significantly increased leaf area index in all the three landraces. The varieties responded to applied N and produced the highest yield in Kutiagni. The DPUSG at 10 DAT increased straw yield but failed to increase grain yield even over control. The DPUSG before PI stage significantly increased rice yield and economic return. The yield of rice in DPUSG applied before PI stage was comparable to two splits of PU and top dressing of PU before PI stage. Compared to control (2.93 t ha⁻¹), yield increase was 26% in Kutiagni (3.70 t ha⁻¹) under DPUSG before PI stage. These results suggest that Kutiagni was more responsive to added N and this cultivar could be cultivated with DPUSG at PI stage.

Keywords: Landrace, nitrogen, lowland ecosystem, rice, yield response.

1. Introduction

Rice (*Oryza sativa* L.) is the common food for more than half of the world population (IRRI, 2013) and it covers 158 million ha of land which produces 490 million tons of milled rice (FAO, 2016). In Bangladesh, rice is the staple food crop and it occupies about 75% of the cropped areas (BBS, 2015). There are three distinct rice growing seasons in Bangladesh like Aus

(cultivated during March to June), Aman (during July to December) and Boro (during January to June). Aman rice is generally grown under rainfed condition. Although, there are some scope for extending modern varieties under rainfed condition but nearly 28% of rice area is still occupied by landraces adaptable to the specific ecosystem (land type, hydrological condition and low nutrient status) of the country (Bhuiyan *et al.*, 2002).

Yield potential of the landraces are however, poor because most of the cultivars are lodging susceptible and non-responsive to high input (Hamid *et al.*, 2004). Thus, yield improvement of the landraces is difficult due to limited application of N, which is considered as the most important plant nutrient for rice throughout the world (Lin *et al.*, 2006). Nitrogen improves crop growth and yield through expansion of leaf area, increases the number of spikelets per panicle, filled grains per panicle and grain N content (Dobermann and Fairhurst, 2000). Generally, the effective use of N in a cropping system depends on adequate rate, suitable source and application time (Fageria *et al.*, 2006). Proper N utilization can improve N uptake and photosynthetic rate, delay in leaf senescence and increase in amount of dry matter for grain filling which may improve the productivity of rice.

However, timing of N application is very important for landraces and N content of soil is low where the landraces are cultivated (Mamun *et al.*, 2015). Application of N at early growing stage mainly contributes to the vegetative development, makes plant bushy and induces lodging. Application of N at mid-tillering stage could be attributed to high losses of N through denitrification, as the plants are not big enough to absorb applied N due to their small root mass (Miah *et al.*, 2016). As the landraces are susceptible to lodging and this problem is accelerated with the applied N, it is imperative to examine the amount and time of N fertilization so that yield improvement of landraces can be done by addressing the problem of lodging. Thus, a suitable N management technique is vital which will increase grain fertility, reduce spikelet sterility and improve rice grain yield. Top dressing of prilled urea and deep placement of urea super granule (USG) are the forms of urea fertilization in Bangladesh. Top dressing of prilled urea is very much popular in rice cultivation all over the country, except in the tidal flood-affected areas. In tidal flooded areas, surface application of N fertilizer like prilled urea is not possible due to high risk of surface loss (Rochette *et al.*, 2013).

In contrast, deep placement of urea reduces N concentration in the floodwater; thus, it reduces N loss and increases uptake by the rice plant. Deep placement of urea increases N use efficiency up to 50 to 70%, increase grain yield by 15 to 20%, and reduces the fertilizer N use by 30 to 40% (IFDC, 2013). The present study was therefore, conducted to investigate the influence of N fertilizer application on the growth and yield of some landrace rice cultivars in lowland ecosystem.

2. Materials and Methods

The experiment was conducted under lowland ecosystem of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur (24°09' N latitude, 90°26' E longitudes), Bangladesh during the rainy season of 2015. The experimental site was characterized by heavy rainfall through out the rice-growing season. The soil of the experimental plot was a silty clay, which contains N of 0.09%, P of 8 ppm, K of 0.29 meq/100 g soil, S of 15 ppm and Zn of 0.7 ppm. The experiment was carried out in a split-plot design with three replications. The treatments included three popular rice landraces placed in the main plot and five times of N application placed in sub-plot. The landraces were Rajashail, Kutiagni, Sadamota, and the five times of N applications were: (i) two splits of prilled urea (PU) applied at 10 days after transplanting (DAT) and before panicle initiation (PI) stage; (ii) Deep placement of urea super granule (DPUSG) at 10 DAT; (iii) DPUSG before PI stage; (iv) PU applied before PI stage; and (v) no urea (control). Nitrogen was applied at the rate of 30 kg N ha⁻¹ in the form of prilled urea (PU) and urea super granule (USG - 1.8 g each ball). A blanket dose of fertilizers of 7-15-7-1 kg P-K-S-Zn ha⁻¹ was applied in 3 m × 3 m plots and was thoroughly incorporated into the soil during final land preparation. Twenty six day-old seedlings were transplanted on 4 August 2015 in 30 cm × 30 cm spacing. The crop was adequately protected from weed, diseases and pests throughout the growing season.

At heading stage, tiller number, leaf area index and dry matter production were determined. Yield and yield components were recorded during harvesting. The panicle density was determined from 16 hills before harvest collected from each plot. The number of grains per panicle was counted and 1000-grain weight was determined from 10 randomly sampled panicles per plot. The grains were separated and counted following standard procedures. Rice grain and straw yields were determined by harvesting 5 m² areas from the middle of each plot. The grains were sun dried and winnowed before weighing and yield was converted into t ha⁻¹. The grain yield was adjusted to 14% moisture content using the following formula:

$$\text{Adjusted weight} = \frac{W \times (100 - M_1)}{(100 - M_2)} \times 100$$

Where, W is the fresh weight; and M₁ and M₂ were the fresh and adjusted moisture percents of the grain, respectively. Harvest index (HI) was computed as:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Grain yield} + \text{Straw yield}} \times 100$$

Grain and straw N concentration was determined from the collected plant samples. The samples were dried at 70^o C for 72 hrs and ground. The ground sample was digested in concentrated H₂PO₄ and total N concentration was determined by micro Kjeldahl method. Nitrogen uptake by grain and straw were determined as:

$$\text{N accumulation in grain (kg ha}^{-1}\text{)} = \frac{\% \text{ N in grain} \times \text{oven dried grain yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{N accumulation in straw (kg ha}^{-1}\text{)} = \frac{\% \text{ N in straw} \times \text{oven dried straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Total N accumulation (kg ha}^{-1}\text{)} = \text{N accumulation in grain} + \text{N accumulation in straw}$$

$$\text{Nitrogen harvest index (\%)} = \frac{\text{N accumulation in grain}}{\text{Total N accumulation}} \times 100$$

The profit from nitrogen (N) fertilization were determined based on: price of N (BDT ha⁻¹); additional labor cost for urea application; additional grain yield (Δ Grain yield) was calculated as the yield difference between N applied plots and no urea applied plot. Net profit (Δ Profit) was calculated as the profit difference between N applied plot yield and no urea applied plot. The local market price of nitrogen fertilizer and rice were considered.

$$\Delta \text{ Grain yield (kg ha}^{-1}\text{)} = \text{Grain yield of N applied plot} - \text{grain yield of no urea applied plot}$$

$$\text{Gross margin (BDT ha}^{-1}\text{)} = \Delta \text{ Grain yield (kg ha}^{-1}\text{)} \times \text{Price of rice (BDT kg}^{-1}\text{)}$$

$$\text{Total cost for N (BDT ha}^{-1}\text{)} = \text{Includes price of N} + \text{labor cost for urea application}$$

$$\text{Profit over N cost (BDT ha}^{-1}\text{)} = \text{Gross margin from urea application} - \text{Cost for N}$$

The collected data were analyzed using a computer software package Crop Stat, version 7.2 (IRRI, 2007). Treatment means were separated with least significant difference (LSD) at the 5% level of probability (Gomez and Gomez, 1984). Graphical analyses were done using Excel software (Microsoft Corporation, Redmond, WA, USA).

3. Results and Discussion

3.1. Growth parameters

Applied N fertilizer exerted significant effects on tillers and dry matter production of landrace rice cultivars Rajashail and Kutiagni but not on Sadamota (Table 1). However, all the landrace rice cultivars were not equally responsive to added N fertilizer. Rajashail produced the highest number of tillers (269 m⁻²) and dry

matter (715 g m^{-2}) under deep placement of urea super granule (DPUSG) before panicle initiation (PI) followed by prilled urea (PU) application before PI stage. Similarly, the highest number of tillers (296 m^{-2}) and dry mass (898 g m^{-2}) of Kutiagni was recorded in DPUSG at 10 DAT and two splits of PU, respectively. The control treatment showed the lowest number of tillers and dry mass in both cultivars. The leaf area index (LAI) of rice cultivars was also differed statistically due to N fertilization. The LAI of Rajashail (4.99), Kutiagni (5.13) and Sadamota (5.10) was the highest with PU before PI followed by DPUSG before PI stage. The control treatment produced the lowest LAI in all cultivars (Table 1). Higher number of tillers and increased dry matter production of the rice cultivars (Table 1) may be due to increase in LAI with the application of N before PI stage. Higher LAI indicates better leaf expansion and canopy structure which attributed to greater interception of solar radiation to produce higher amount of dry matter. The DPUSG at later growth stage of rice ensure continuous supply of N to the crop that helps the leaves to stay green for longer time. Nitrogen is a component of chlorophyll (photosynthetic molecule) and essential for many enzymatic functions in the plant body (Fageria, 2014). Application of N at PI stage showed better LAI and higher leaf chlorophyll content also reported by Bah *et al.* (2009). The authors reported that N fertilizer increased leaf

expansion rate, leading to intercept more solar radiation by the crop canopy and enhanced dry matter production. Further, applied N increased cell division resulting taller plant and production of more tiller of rice (Chaturvedi, 2005). Dobermann *et al.* (2002) stated that application of N fertilizer before or at PI stage helped produce higher leaf, stem and panicle biomass that lead to increase plant dry matter content.

3.2. Yield components and grain yield

Interaction of N fertilizer with landrace rice cultivars demonstrated a significant effect on panicle production of landrace rice cultivars (Table 2). The variety Rajashail produced the highest number of panicles m^{-2} under DPUSG at 10 DAT which was statistically similar with that of other treatments. In case of Kutiagni, maximum number of panicles m^{-2} was recorded from application of PU before PI followed by DPUSG at 10 DAT. The cultivar Sadamota produced higher number of panicles m^{-2} with the application of PU before PI. For all varieties, control (no urea-applied plots) produced the lowest number of panicles m^{-2} . Number of panicles per unit area is the most important yield contributing trait which can be manipulated significantly with the N fertilization application at an appropriate growth stage during the crop growth cycle. Nitrogen applied late during the reproductive growth stage could be absorbed by the crop (Fageria and Baligar, 1999).

Table 1. Effect of N fertilization on growth parameters at heading of landrace rice cultivars

Nitrogen fertilization	Tillers (no. m^{-2})			Dry matter (g m^{-2})			Leaf area index		
	Raja shail	Kutia gni	Sada mota	Raja shail	Kutia gni	Sada mota	Raja shail	Kutia gni	Sada mota
Two splits of PU	232	279	216	509	898	752	4.18	4.17	4.32
DPUSG at 10 DAT	238	296	231	561	805	804	3.87	4.02	4.10
DPUSG before PI	269	261	197	715	733	911	4.55	4.64	4.60
PU before PI	242	289	184	632	767	807	4.99	5.13	5.10
No urea	199	247	203	483	741	805	3.02	3.12	3.30
LSD _{0.05} for N	46	30	NS	154	147	NS	0.87	0.12	0.33
N × Variety		38			188.95			0.20	
CV (%)		9.3			15.2			2.8	

PU = Prilled urea, DPUSG = deep placement of urea super granule, DAT = Days after transplanting, PI = Panicle initiation and NS = Not significant

Table 2. Effect of N fertilization on yield components of landrace rice cultivars at harvest

Nitrogen fertilization	Panicles m ⁻² (no.)			Grain yield (t ha ⁻¹)			Harvest index (%)		
	Raja shail	Kuti agni	Sada mota	Raja shail	Kuti agni	Sada mota	Raja shail	Kuti agni	Sada mota
Two splits of PU	200	191	144	2.90	3.61	3.22	43	39	38
DPUSG at 10 DAT	219	206	142	2.70	3.21	2.75	41	40	34
DPUSG before PI	206	189	137	3.09	3.70	3.08	45	42	38
PU before PI	212	218	163	2.79	3.44	3.22	41	35	36
No urea	190	188	135	2.65	2.93	2.54	45	38	37
LSD _{0.05} for N	NS	NS	NS	NS	0.28	NS	NS	4.56	NS
N × Variety		35.85			0.48			7.28	
CV (%)		11.5			9.2			10.08	

PU = Prilled urea, DPUSG = deep placement of urea super granule, DAT = Days after transplanting, PI = Panicle initiation and NS = Not significant

The N fertilization and cultivar interacted significantly to influence grain yield. Similarly, N fertilization exerted a significant effect on grain yield of Kutiagni (Table 2). The cultivar Kutiagni produced the highest grain yield (3.70 t ha⁻¹) in DPUSG before PI treatment. The second highest grain yield (3.61 t ha⁻¹) was recorded from two splits of PU followed by PU before PI stage. Higher yield of cultivar Kutiagni was attributed due to increase in number of panicles under applied N through DPUSG before PI stage. In case of Rajashail, numerically higher grain yield obtained from DPUSG before PI which was statistically similar with that in other N treatments. Sadamota yielded the highest in both two splits of PU and application of PU before PI, which were statistically similar with that in DPUSG before PI treatment. On the other hand, DPUSG at 10 DAT and control plot produced statistically similar grain yields for all varieties. Although two splits of PU and top dressing of PU before PI gave satisfactory yield in all the cultivars, but there is little scope for broadcasting of PU due to surface and volatilization loss through flash flood water under heavy rainfall condition. Although application of DPUSG at 10 DAT produced the highest number of panicles m⁻² it gave the lowest grain yield than other treatments in all the cultivars (Table 2). It indicates that the application of N at early crop growth stage may not be utilized by the grains of landrace rice

cultivars because most of the N contributed to vegetative growth. Thus, the results suggest that the application of N at later growth stage either as DPUSG or as PU synchronize with the crop demand and making it possible for the plant to translocate more N to the grain. The application of N through DPUSG before PI stage increased grain yield at a range between 0.5 to 1.0 t ha⁻¹ (Table 2). However, the grain yield obtained by DPUSG before PI was much higher than that by DPUSG at 10 DAT.

The yield of Kutiagni and Sadamota in DPUSG before PI was comparable with that in two splits of PU and PU before PI. In the present experiments, the improved grain yield with DPUSG before PI stage might be due to production of higher number of panicles m⁻² and absorbing more N at the booting and flowering growth stages of rice (Castillo *et al.*, 1992). Moreover, many earlier studies showed that the yield of rice increased with DPUSG compared to top dressing of urea (Gregory *et al.*, 2010; Bandaogo *et al.*, 2015). However, Abedin *et al.* (2015) found no significant yield variation with the application of N in landrace rice. The harvest index (HI) of Kutiagni differed significantly with N fertilization (Table 2). Kutiagni showed the highest HI (42%) in DPUSG before PI which was significantly higher than that in PU before PI stage.

3.3. Nitrogen uptake

Nitrogen fertilization exerted significant effect on N uptake by the grains of Kutiagni and Sadamota (Table 3). The highest amount of N was accumulated by the grains of Kutiagni (36.08 kg ha⁻¹) and Sadamota (31.55 kg ha⁻¹) in DPUSG and PU before PI stage, respectively although it was non-significant in case of Rajashail. Considering total N uptake, the highest amount of N was taken up by cultivars Rajashail and Kutiagni in DPUSG before PI stage, which was statistically identical with that in two splits of PU. All the landrace rice cultivars accumulated lower amounts of N in no urea plot. Nitrogen fertilizer application and rice cultivar interacted to influence nitrogen harvest index (NHI) significantly. Similarly, N fertilization also exhibited significant effect on NHI of Kutiagni and Sadamota (Table 3).

The highest NHI of Kutiagni and Sadamota obtained from DPUSG before PI and no urea treatment, respectively. In case of Rajashail, higher NHI recorded from no urea treatment. Nitrogen content of rice cultivars markedly increased with the application of N fertilizer. Mamun *et al.* (2016) stated that landrace rice cultivars like Sadamota, Lalmota and Moulta absorbed more amount of N in N treated plot. Fageria *et al.* (2010) also reported that the grain N concentration was low at low N level. However, the cultivars accumulated more

amount of N with application of either DPUSG or PU before PI stage. This indicates that the N applied at the later growth stage of rice absorbed by both grain and straw. Application of N at PI stage helped absorb more N by the rice plant as reported by other authors (Tylaran *et al.*, 2009; Mamun *et al.*, 2017). Fageria and Baligar (1999) also reported that N applied during reproductive growth stage absorbed by the crop, which was utilized to improve grain yield. Nitrogen uptake by rice showed a significant linear association with grain yield (Figures 2 and 3) which confirmed the beneficial effect of application of N at reproductive stage of rice as observed in the present study. Fageria (2014) stated that variation in grain yield due to N uptake in grain and shoot was 70 and 47%, respectively. This means that N uptake in grain has higher correlation with grain yield compared to shoot. Consequently, better capability of landrace Kutiagni to uptake higher amount of N in grain and total N in plant prepared itself outstanding to increase grain yield under unfavorable lowland ecosystem.

Shoot biomass yield at heading showed a linear relationship with grain yield (Figure 1) of all rice cultivars. Hence, increasing shoot dry weight can increase grain yield. Other authors (Peng *et al.*, 2000; Fageria and Barbosa, 2001) also reported that grain yield of lowland rice increased significantly with increasing shoot dry weight.

Table 3. Effect of N fertilization on grain and straw yield of landrace rice cultivars

Nitrogen fertilization	Grains N uptake (kg ha ⁻¹)			Total N uptake (kg ha ⁻¹)			N harvest index (%)		
	Raja shail	Kuti agni	Sada mota	Raja shail	Kuti agni	Sada mota	Raja shail	Kuti agni	Sada mota
Two splits of PU	27.15	32.54	31.46	50.90	59.51	56.65	53.58	54.71	55.60
DPUSG at 10 DAT	25.86	27.44	27.28	45.55	53.73	49.50	56.71	50.05	48.46
DPUSG before PI	31.41	36.08	29.72	56.25	60.05	53.67	55.48	60.31	54.65
PU before PI	27.27	30.79	31.55	46.92	56.17	57.08	58.71	54.90	55.55
No urea	25.52	26.78	23.76	42.55	46.92	46.68	60.00	58.52	58.95
LSD _{0.05} for N	NS	3.83	6.79	8.89	7.38	NS	NS	5.54	9.03
N × Variety		5.29			9.61			10.77	
CV (%)		10.7			10.8			11.4	

PU = Prilled urea, DPUSG = deep placement of urea super granule, DAT = Days after transplanting, PI = Panicle initiation and NS = Not significant

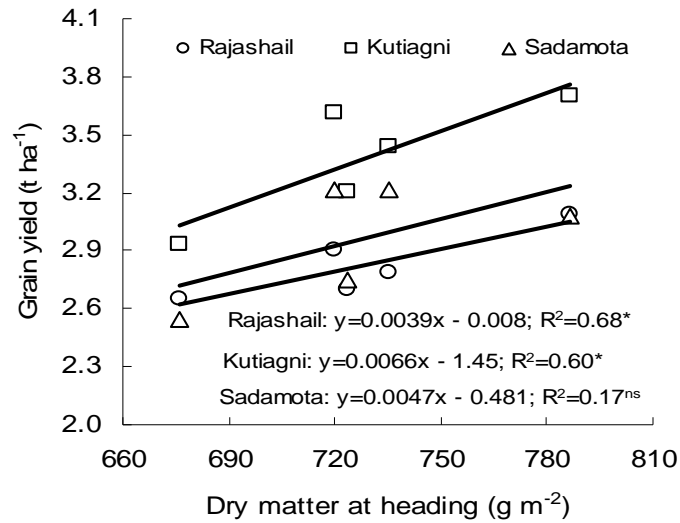


Figure 1. Relationship between dry matter production at heading and grain yield of Aman rice; * and NS = significant at 5% level and not significant, respectively.

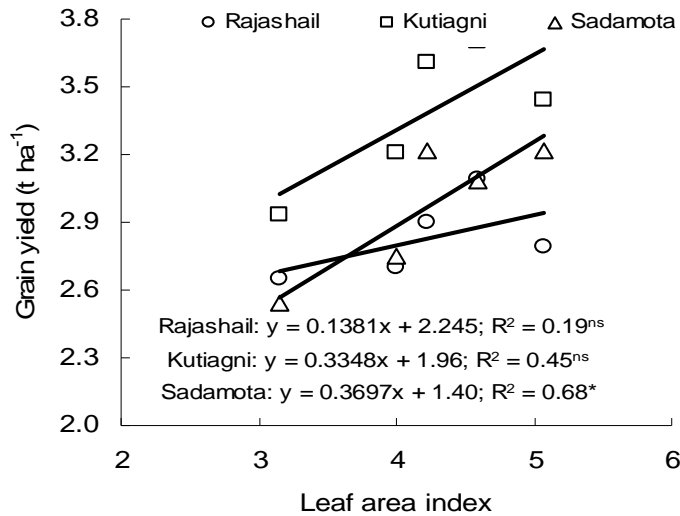


Figure 2. Relationship between leaf area index and grain yield of Aman rice; * and NS = significant at 5% level and not significant, respectively.

There was a significant linear relationship between leaf area index (LAI) and grain yield (Figure 2) in all tested cultivars. However, the

relationship was significant in case of Sadamota ($R^2=0.68^*$) but not for Rajashail and Kutiagni (Table 4).

The grain yield had a linear association with grain N content in all cultivars (Figure 3). All the significant relationships indicated that grain yield increases with increasing of grain N absorption. The accumulation of N in grain accounted 85, 95 and 66% variation for Rajashail, Kutiagni and Sadamota, respectively

(Table 4). The relationships were $y = 0.058x + 1.129$, $R^2 = 0.85^{**}$ for Rajashail; $y = 0.1078x + 0.25$, $R^2 = 0.95^{**}$ for Kutiagni and $y = 0.0926x + 0.2785$, $R^2 = 0.66^*$ for Sadamota. Fageria (2014) reported that variation in grain yield due to N uptake in grain and shoot was 70 and 47%, respectively.

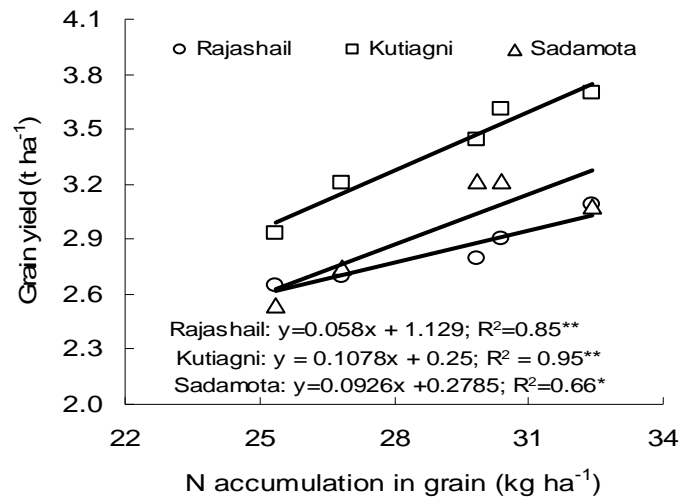


Figure 3. Relationship between grain N accumulation and grain yield of Aman rice; * and ** = significant at 5 and 1% level, respectively.

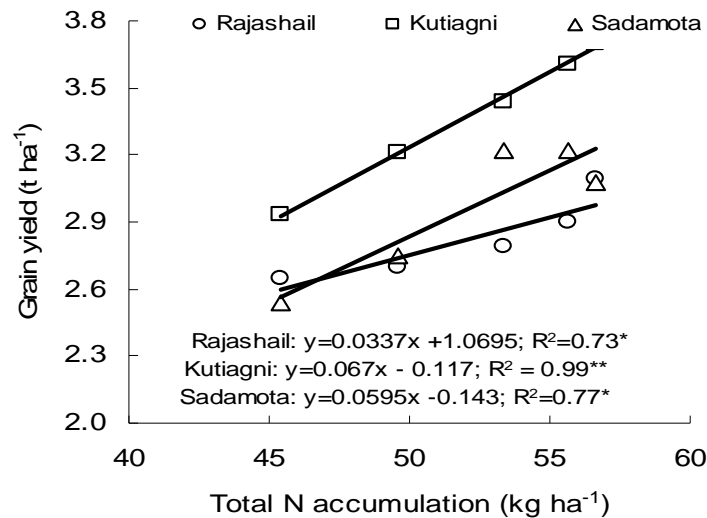


Figure 4. Relationship between total N accumulation and grain yield of Aman rice; * and ** = significant at 5 and 1% level, respectively.

Table 4. Associations of grain yield with different growth parameters and N content of landrace rice cultivars

Variables	Cultivars	Adjusted R ²	F-value	Probability level
Dry matter production at heading vs. grain yield of landrace rice cultivars	Rajashail	0.69*	9.70	0.05
	Kutiagni	0.60*	7.02	0.05
	Sadamota	0.17 ^{ns}	1.81	0.27
Leaf area index at heading vs. grain yield of landrace rice cultivars	Rajashail	0.19 ^{ns}	1.41	0.32
	Kutiagni	0.45 ^{ns}	4.23	0.12
	Sadamota	0.68*	9.75	0.05
N accumulation in grain vs. grain yield of landrace rice cultivars	Rajashail	0.85**	25.02	0.01
	Kutiagni	0.95**	66.07	0.01
	Sadamota	0.66*	8.75	0.05
Total N accumulation vs. grain yield of landrace rice cultivars	Rajashail	0.73*	11.82	0.05
	Kutiagni	0.99**	1284	0.01
	Sadamota	0.77*	14.70	0.05

*, ** and NS = significant at 5 and 1% level; and not significant, respectively.

There was a significant linear relationship between total N absorption and grain yield in all cultivars (Figure 4). However, the relationships were significant for all cultivars. The relationships were $y = 0.0337x + 1.0695$, $R^2 = 0.73^*$ for Rajashail; $y = 0.067x - 0.117$, $R^2 = 0.99^{**}$ for Kutiagni and $y = 0.0595x - 0.143$, $R^2 = 0.77^{**}$ for Sadamota (Table 4).

4. Economic analysis

Rajashail produced 440 kg more grains ha⁻¹ in DPUSG before PI (Table 5). On the other hand, Kutiagni and Sadamota gave yield advantage of 680 kg ha⁻¹ in two splits of PU. However, 770 and 540 kg more grains ha⁻¹ was recorded from Kutiagni and Sadamota in DPUSG before PI. Application of PU before PI also gave yield advantage by more than 500 kg ha⁻¹ in Kutiagni and Sadamota. Hence, maximum gross margin was obtained from Rajashail and Kutiagni with DPUSG before PI. However, Sadamota gave maximum gross margin in both two splits of PU and PU before PI (Table 6).

Moreover, application of DPUSG before PI gave maximum gross margin but it needed higher fertilizer cost than other treatments (Table 6). Lower fertilizer cost was involved in application of PU before PI treatment. Therefore, maximum profit was obtained from Sadamota in PU before

PI (Table 6). However, Rajashail and Kutiagni gave maximum profit in DPUSG before PI. Though DPUSG in rice required more labor cost compared to broadcasting of prilled urea (PU) or control, but it increased grain yield and farm profit (Tables 5 and 6). The DPUSG involved more cost compared to PU or control was well-documented by many previous studies conducted in Bangladesh (Gregory *et al.*, 2010; Miah *et al.*, 2016). The DPUSG was done by hand and the cost of fertilizer includes the cost of purchasing N and application cost. Other intercultural practices such as transplanting, gap filling, weeding, harvesting, etc. were considered equally for all treatments. The cost for DPUSG varies location to location depending on the working efficiency of the labors (Thompson and Sanabria, 2010).

Therefore, difference in fertilizer cost including its application was considered for economic comparison. Net profit was calculated as the profit difference between DPUSG yield and no urea applied plot. The local market prices of nitrogen fertilizer and rice were considered. The study confirmed that yield response and gross margin was higher in DPUSG before PI treatment plot (Table 5 and Table 6). Maximum profit was obtained from DPUSG before PI in case of Rajashail and Kutiagni.

Table 5. Yield response to N fertilization and gross margin of landrace rice cultivars

Nitrogen fertilization	Δ Grain yield (kg ha ⁻¹)			Gross margin (BDT ha ⁻¹)		
	Rajashail	Kutiagni	Sadamota	Rajashail	Kutiagni	Sadamota
Two splits of PU	250	680	680	3750	10200	10200
DPUSG at 10 DAT	50	280	210	750	4200	3150
DPUSG before PI	440	770	540	6600	11550	8100
PU before PI	140	510	680	2100	7650	10200
LSD _{0.05}	NS	219	NS	NS	3287	6121
CV (%)	33.5	19.7	38.3	27.3	19.7	38.8

PU = Prilled urea; DPUSG = deep placement of urea super granule; DAT = Days after transplanting; PI = Panicle initiation; Price of rice = 15.0 BDT kg⁻¹; BDT = Bangladeshi Taka.

Table 6. Cost and profit due to N fertilization in landrace rice cultivars

Nitrogen fertilization	Price of N (BDT kg ⁻¹)	Labors (no. ha ⁻¹)	Total cost for N (BDT ha ⁻¹)	Profit over N cost (BDT ha ⁻¹)		
				Rajashail	Kutiagni	Sadamota
Two splits of PU	34.72	4	2442	1308	7758	7758
DPUSG at 10 DAT	47.74	3	2482	-1732	1718	668
DPUSG before PI	47.74	4	2832	3768	8718	5268
PU before PI	34.72	3	2092	8	5558	8108
LSD _{0.05}				NS	3011	6050
CV (%)				88.3	21.2	45.5

PU = Prilled urea; DPUSG = deep placement of urea super granule; DAT = Days after transplanting; PI = Panicle initiation; BDT = Bangladeshi Taka, Amount of N applied = 30 kg ha⁻¹; labor cost = 350.0 BDT man-day⁻¹.

However, Sadamota gave maximum profit in PU before PI. Application of DPUSG at 10 DAT failed to give better yield, gross margin and profit in all varieties. Miah *et al.* (2016) and Mamun *et al.* (2017) also stated that DPUSG increased grain yield and provided higher economic return in rice cultivation during Aman season.

4. Conclusions

Rajashail, Kutiagni and Sadamota are very popular landrace rice cultivars for Aman season and N deficiency is one of the most yield limiting factors for this crop in southern region of Bangladesh. This study showed that application of N fertilizer significantly increased tiller production, leaf area index, dry matter, panicle production and N accumulation in grains resulting in improved grain yields. These results

revealed that the landrace rice cultivar Kutiagni was responsive to applied N. More than half ton yield advantage might be obtained through DPUSG before PI stage of landraces Aman rice cultivar Kutiagni that added farm income up to 8718 BDT ha⁻¹. It may be concluded that landrace rice cultivar Kutigani could be cultivated with the application of DPUSG at PI stage.

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