



Effect of nitrogen management and seedling raising methods on the productivity of *Aus* rice under tidal ecosystem of Bangladesh

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Abstract

The low productivity of *Aus* rice in the tidal ecosystem of Bangladesh is mainly due to the difficulties in nitrogen (N) management under high tidal water along with unavailability of irrigation water during the onset of rice cultivation. Our present study demonstrated how the productivity of *Aus* rice could be improved using appropriate seedling raising methods and N management practices. The study was laid out in split plot design consisting two factors *viz.*, seedling raising methods (wet seed bed and dry seed bed) and N management practices (six N treatments) in three replications. Results indicated that both the seedling raising methods and N management practices had significant effect on all the yield contributing characters of transplanted *Aus* rice under tidal condition. Specifically, the combination of seedlings raised in wet seed bed and fertilized with urea super granule (USG) at 10 days after transplanting (DAT) *i.e.*, N₃W showed the best values for plant height (110.33cm), number of effective tillers hill⁻¹ (14.60), days required 50% flowering (53.00 DAT), days to maturity (84.33 DAT), panicle length (23.37 cm), number of filled grain panicle⁻¹ (88.13), 1000-grain weight (43.17 g), grain yield (4.62 tha⁻¹), straw yield (6.07 tha⁻¹), biological yield (10.67 tha⁻¹), and harvest index (43.17%). However, in considering the productivity/ grain yield, besides N₃W, the whole urea application at land preparation along with wet seed bed (N₁W) and USG application along with dry seed bed (N₃D) also produced statistically similar results ($p < 0.01$) and thus all these three combinations may be practiced for improving productivity and ensuring horizontal expansion of *Aus* rice in the tidal ecosystem of Bangladesh.

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Introduction

Rice (*Oryza sativa* L.) is the most important staple food crops for over half of the world's population and over 759.6 Mt of rice was produced globally in 2017 (FAO 2018). Near about 90% of annual rice is produced and consumed in Asia. The average yield in Asia is low compared to global mean yield (Haider 2018). More than two billion people in Asia are dependent on rice for their livelihood (Xiong et al., 2013). The demand for rice is increasing to meet the demand of rising population. And, the possible way to meet this increases demand by improvement of rice yield per hectare (Liu et al., 2016). In Bangladesh, about 75% of the total cropped area and over 80% of the total irrigated area is occupied by rice (BBS, 2013). Thus, rice plays a vital role in the livelihood of the people of Bangladesh. There are

three rice growing season viz. *Aus*, *Aman* & *Boro* in Bangladesh which are cultivated during *Kharif-1* (April–July), *Kharif-2* (July–November) and *Rabi* (November–April), respectively. After the 1980s, *Aus* production slowly began to lose priority to the farmers as they shifted to irrigated *Boro* rice cultivation due to its higher yield (BRRRI 2011). The Government of Bangladesh has given top priority for increasing the area and production of *Aus* rice to reduce the pressure on electricity for irrigation needed for *Boro* rice production during dry season. Compare to *Boro*, *Aus* requires less irrigation and the plan is to cut dependency on the underground water for irrigation and arrest the fall in the water level in the aquifer. *Aus* rice in this regard can create scope by scaling up production and shed dependency on the underground water (UNB 2017). But the main drawback is the average yield of *Aus* rice (2.16 t ha⁻¹) which is lower than *Aman* and *Boro* rice (BBS 2013). Using the latest high yielding varieties of transplanted *Aus* rice along with improved cultivation techniques might be the best possible options to meet this productivity gap of *Aus* rice. Bangladesh occupies most lands of the great Bengal plane of the Ganges Delta with affluent alluvial soils. And, the overall natural climate and geographic condition of Bangladesh is blissful for growing *Aus* rice. The main problem is insufficient rainfall in April-May with which wet nursery bed preparation and transplanting is very difficult. So, preparation of wet nursery bed and transplant *Aus* rice seedlings using the tidal water may be a good option. Since water is not easily available and time of *Aus* planting uncertain, dry nursery bed may be alternative option by the farmers of tidal area. However, till date there is no such comparative study on the yield variability of transplanted rice between wet and dry nursery bed.

Besides, the management of nitrogenous fertilizer (either as basal or top dressing) is difficult due to high depth of water during cultivation period. Nitrogen (N) is the key element in the production of rice. But, the N management in the tidal areas is always a great challenge. To improve rice yield supplementation of N fertilizer under most agro-ecosystem has been suggested (Fageria and Santos, 2014). Nitrogen helps to increase rice productivity through improving leaf N concentration, photosynthetic rate, delaying leaf senescence, and increasing dry matter for grain filling (Hasegawa et al., 1994). Moreover, N may also play great role in improving panicle size, grain weight and reducing spikelet sterility (Fageria, 2009). Application of N fertilizer in rice has also been reported to significantly increase the grain and straw N uptake and N use efficiency (Hassan et al., 2009). Normally, farmers in the developing countries apply N in two ways. One is broadcasting of prilled urea (PU), which is the common practice in Bangladesh and another is urea deep placement (UDP) in the form of urea super granule (USG). It has been reported that compared to UDP, the main problem of PU is the N volatilization loss as ammonia (Rochette et al., 2013). Basically the use efficiency of urea is very low and the recovery of N, especially in wetland rice field rarely exceeds 40% (De Datta, 1989). However, minimizing of N losses in the environment was also possible by applying urea to plants through the foliage (Giroux 1984 & Millard and Robinson 1990). In several researches it has been observed that most of the plants rapidly can absorb liquid urea and hydrolyze the absorbed urea in the cytosol subsequently ensure better assimilation in the plants' system which help to increase N use efficiency (Wittwer et al. 1963, Nicoulaud and Bloom 1996 and Lam et al. 1996)

At this point, our present study has been designed to find out the effect of suitable N management practices along with different seedling raising methods viz. wet and dry bed on the yield and yield contributing characters of tidal *Aus* rice and thus, to unlock the potentials of horizontal expansion of *Aus* rice cultivation in the coastal areas of Bangladesh.

Materials and Methods

Experimental location and climate

The study was carried out at the Agronomy Field Laboratory of Patuakhali Science and Technology University (PSTU), Patuakhali, Bangladesh from April to August, 2017. The experimental field was located under Ganges Tidal Floodplain Agro-ecological Zone (AEZ) 13. This region occupies an extensive area of coastal tidal floodplain land in the south–west of the country. The area lies at 0.9 to 2.1 meter above mean sea level. The study area was located under the sub-tropical climate, which is specialized by moderately high temperature and heavy rainfall during the *Kharif-1* (March to August) and *Kharif-2* season (April–September) and low rainfall with moderately low temperature during *Robi* season (October–March).

The experimental field was flooded twice daily by tidal inundation. The magnitude of tidal water depth, flow of water and stagnation period of water depends mainly on the moon-month, wind speed, wind direction and air pressure that attains peak in May–August (Figure 1). The highest water depth of the field were observed at the beginning and mid of the moon-month. The data were collected every two days interval from transplanting (14th May) to harvesting date (31th July).

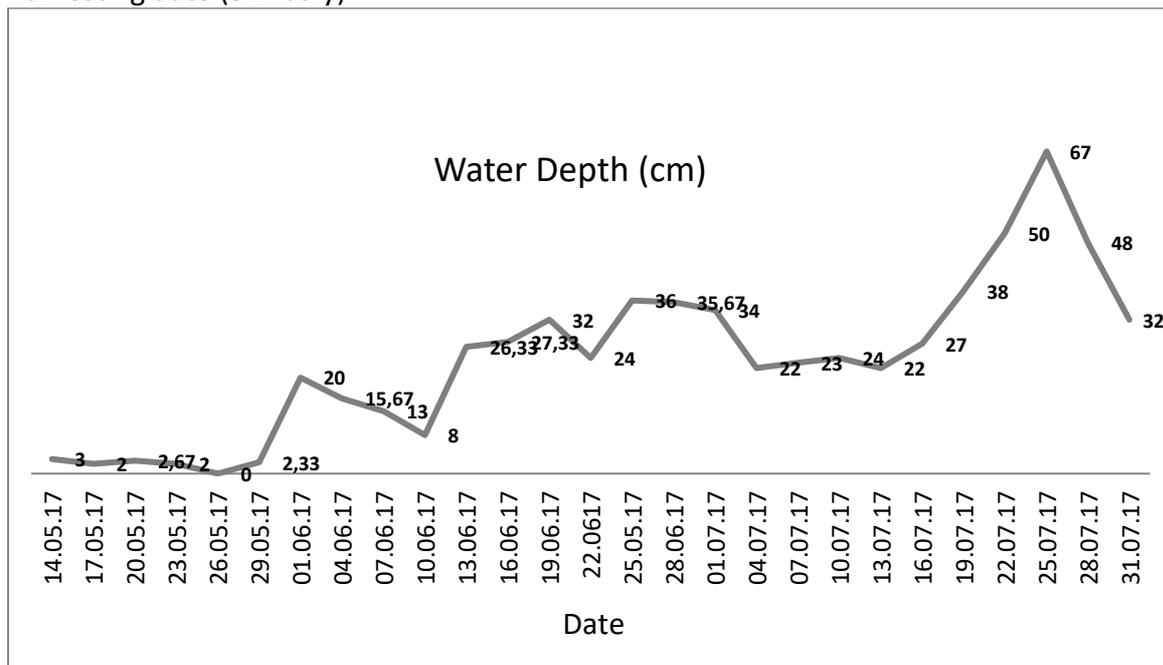


Figure 1. Height of water (in cm) in the experimental field of transplant *Aus* rice from transplanting to harvesting

Experimental Procedure

The study was a two factor experiment with three replications where two sets of experimental treatments included in the study as factor-A (six nitrogen management practices) and factor-B (two seedling raising methods) have been presented in Table 1. The experiment was laid out in a split-plot design where twelve (12) treatment combinations were allocated in 36 plots of 8 m² size (5m x 1.6m). BRRIdhan55, an *Aus* rice variety developed by Bangladesh Rice Research Institute (BRRI) was used as experimental materials.

Table 1. List of treatments used in the experiment

Factor-A: Six (6) nitrogen management practices
N ₀ : No nitrogen
N ₁ : Whole urea at land preparation @ 150kg ha ⁻¹ as recommended dose
N ₂ : Urea Super Granule (USG) at Land preparation @ 112 kg ha ⁻¹
N ₃ : USG @ 1.8g (granule) per 4 hill (112kg ha ⁻¹) at 10 days after transplanting (DAT)
N ₄ : 50% urea of recommended dose+ 2% urea spray at 30, 45 and 60 DAT (105 Kg)
N ₅ : 50% urea of recommended dose at land preparation + Magic growth spray at 30, 45 and 60 days
Factor-B: Two (2) seedling raising methods
W: Wet seedbed
D: Dry seedbed

Fertilizer management

The experimental plots were fertilized as per Fertilizer Recommendation Guide BARC (2012). Besides, different nitrogenous fertilizers were applied following the procedure as mentioned below-

Urea spray: Liquid urea used in the experiment for foliar spray was prepared by mixing 2 kg of prilled urea in 100 L of water as per treatment. The urea was sprayed @ 500L/ha of spray volume at 30, 45 and 60 DAT.

Magic growth spray: Magic growth is a solution of different nutrient elements and it contains 10.51% total nitrogen, 5.58% phosphorous, 6.33% potassium, 0.10% sulphur, 0.16% zinc, 0.04% copper, 0.0006% iron, 0.006% manganese, 0.25% boron, 0.07% calcium and 0.007% magnesium. The spray volume of magic growth was prepared by mixing fifty (50) ml magic growth with 1L water. This mixture was sprayed @ 500L /ha at 30, 45 and 60 DAT.

Urea Super Granule (USG): USG fertilizer is manufactured from a physical modification of prilled urea (PU) fertilizer. The International Fertilizer Development Center (IFDC) has developed it. Its nature and properties are similar to that of urea but its granule size is bigger and condensed with some conditions for slow hydrolysis. USG is spherical in shape containing 46% N which is similar to that of PU.

Preparation of seedbed and sowing

Wet seed bed (W): Wet nursery bed was prepared under irrigated condition. The soil was puddled by three ploughing and cross ploughing with cultivator. The sprouted seeds were sown in the prepared seedbeds on 18th April, 2017. The size of seed bed was 15 m² (length 5m & width 1.5×2m).

Dry seed bed (D): The land was first ploughed, cross ploughed and then harrowed until a good tilth condition is attained. The seeds were sown in the prepared dry seedbed on 15th April, 2017. The seed bed size was 15 m².

Data collection and statistical analysis

Different yield and yield contributing data viz. plant height (cm), number of effective tillers hill⁻¹, days to first flowering, days to 50% flowering, number of non-effective tillers hill⁻¹, days to maturity, panicle length (cm), number of filled grains panicle⁻¹, number of unfilled grains panicle⁻¹, thousand grain weight (g), grain yield (t ha⁻¹), straw yield (t ha⁻¹), biological yield (t ha⁻¹) and harvest index (%) were collected and analysis of variance (ANOVA) was calculated with the help of computer software package MSTAT-C program (Russel 1986). The

mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significant (Gomez and Gomez 1984).

Results and Discussion

In our study different nitrogen management practices and seedling raising methods were found to have significant roles on all the yield and yield contributing characters of *Aus* rice under tidal ecosystem. The results are presented below in respect to different important growth and yield parameters of transplanted *Aus* rice.

Plant height

Nitrogen management had significant effect on plant height ($p < 0.01$; Figure 2). Among all the N management treatments, maximum plant height (109.17 cm) was observed in N_3 treatment [USG @ 1.8g (granule) per 4 hill (112kg/ha) at 10 DAT] and the shortest plant (97.73 cm) was recorded in case of N_0 treatment (without nitrogen) (Figure 2). Our data is also in accordance with Ilaga and Daya (1989) regarding plant height in response to nitrogenous fertilizers. Plant height was also significantly influenced by seedling raising methods ($p < 0.01$; Figure 2) where in case of seedlings raised in wet seed bed were found as longest (104.23cm) compared to the seedlings raised in dry seed bed (99.61 cm). Interaction of nitrogen management and seedling raising methods had significant effect on plant height of *Aus* rice ($p < 0.01$; Table 2). The maximum plant height (110.33 cm) was found in N_3W treatment combination i.e., USG at 10 DAT in combination for the seedlings raised in wet bed and the lowest plant height (94.00 cm) was obtained in N_0D treatment i.e. without nitrogen in case of the seedlings raised in the dry bed. We also observed highest plant height of 108.00 cm from the treatment N_3 the raised seedlings in dry bed (N_3D) which was statistically at par with N_3W . Using of the urea deep placement technology (USG) has already proven increased yield in several studies (Bandaogo et al., 2015; Alam et al., 2013; Gregory et al., 2010; Mohanty et al., 1999; Savant and Stangel, 1990). Increased plant height might be the response of enhanced availability of nitrogen from USG.

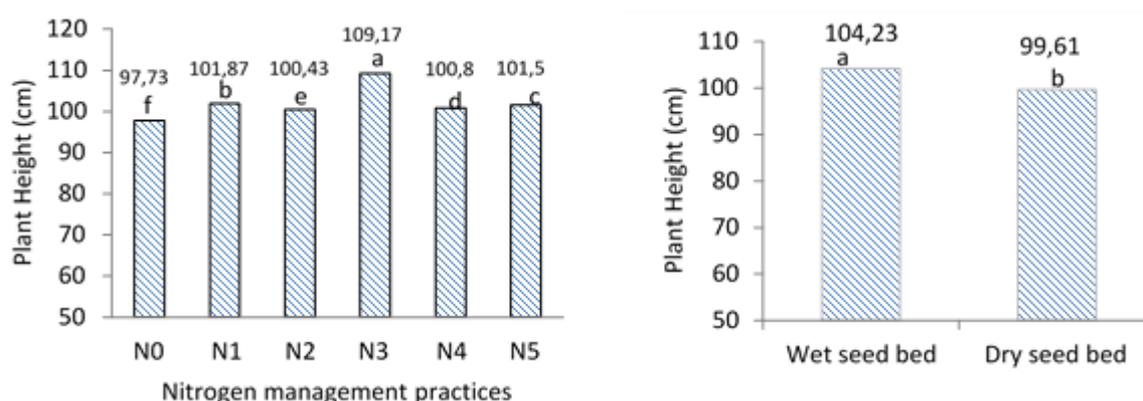


Figure 2. Effect of different nitrogen management practices and seedling raising methods on the plant height of transplant *Aus* rice. (N_0 = No nitrogen, N_1 =Whole urea at land preparation @ 150kg/ha, N_2 =USG at LP @ 112 kg/ha, N_3 = USG @ 1.8g (granule) per 4 hill (112kg/ha) at 10 DAT, N_4 = 50% urea + 2 % urea spray at 30, 45 and 60 DAT, N_5 =50% urea at land preparation + Magic growth spray at 30, 45 and 60 days). Same letter on the bars do not differ significantly as per DMRT ($p < 0.01$).

Table 2. Interaction effect of nitrogen management and seedling raising methods on plant height and effective tillers of transplant *Aus* rice

Interaction	Plant height (cm)	No. of effective tillers hill ⁻¹
N ₀ W	101.47 bc	13.13 ab
N ₁ W	103.67 b	14.47 a
N ₂ W	103.33 b	13.33 ab
N ₃ W	110.33 a	14.60 a
N ₄ W	103.90 b	14.40
N ₅ W	102.67 bc	13.77 ab
N ₀ D	94.00 c	10.73 c
N ₁ D	100.07 bc	13.07 ab
N ₂ D	97.53 bc	12.33 b
N ₃ D	108.00 ab	14.20 a
N ₄ D	97.70 bc	11.93 bc
N ₅ D	100.33 bc	13.33 ab
Significance level	**	**
CV (%)	4.30	8.85

Note: In a column, figures with same letter or without letter do not differ significantly as per DMRT; ‘***’ = Significant at 1%; N₀= No nitrogen, N₁=Whole urea at land preparation @ 150kg/ha, N₂=USG at LP @ 112 kg/ha, N₃= USG @ 1.8g (granule) per 4 hill (112kg/ha) at 10 DAT, N₄= 50% urea + 2 % urea spray at 30, 45 and 60 DAT, N₅=50% urea at land preparation + Magic growth spray at 30, 45 and 60 days. W=wet seed bed and D=Dry seed bed; CV (%) = Percent coefficient of variation.

Effective tillers hill-1

In case of effective tillers per hill, the effect of different N management options were highly significant ($p < 0.01$; Figure 3). The maximum number of effective tillers hill⁻¹ (14.40) was observed from the application of USG at 10 DAT (N₃) and the lowest number of effective tillers hill⁻¹ (11.93) was found from no nitrogen treatment (N₀). Adequacy of nitrogen from USG probably favored the cellular activity during tiller formation and development, which led to increased number of effective tillers hill⁻¹.

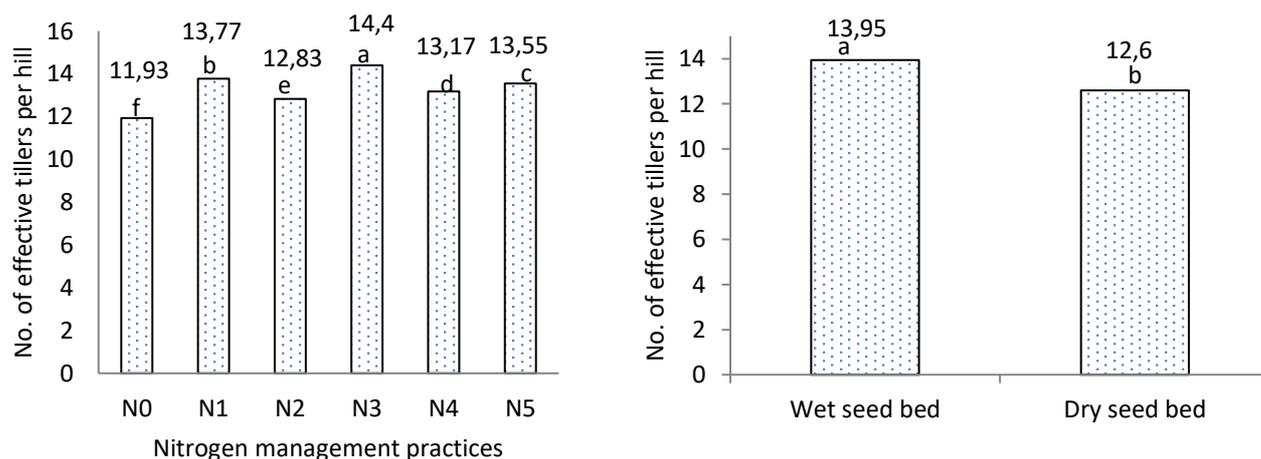


Figure 3. Effect of different nitrogen management practices and seedling raising methods on effective tillers hill⁻¹ of transplant *Aus* rice. (N0= No nitrogen, N1=Whole urea at land preparation @ 150kg/ha, N2=USG at LP @ 112 kg/ha, N3= USG @ 1.8g (granule) per 4 hill (112kg/ha) at 10 DAT, N4= 50% urea + 2 % urea spray at 30, 45 and 60 DAT, N5=50% urea at land preparation + Magic growth spray at 30, 45 and 60 days). Same letter on the bars do not differ significantly as per DMRT ($p < 0.01$).

Ahmed *et al.* (2005) also reported that number of effective tillers hill⁻¹ increased with the better management of nitrogen. Again, between the two seedling raising methods the number of effective tillers hill⁻¹ was also significantly influenced. In case of wet seed bed raised seedling the highest number of effective tillers was recorded (13.95) while this number in case of dry seed bed raised seedlings was 12.60 (Figure 3). The interaction effect of nitrogen management and seedling raising method on number of effective tillers hill⁻¹ was significant (Table 2). The number of effective tillers hill⁻¹ ranged from 10.73 to 14.60 over the treatments. The highest number of effective tillers hill⁻¹ (14.60) was obtained with N₃W which was statistically similar to N₄W and N₁W and the lowest number of effective tillers hill⁻¹ (10.73) with N₀D. Increased N absorption had great role in increasing number of tillers per square meter (Yoshida *et al.* 1972).

Days to 50% flowering and maturity

Different N management practices had significant effect on flowering and maturity of transplant *Aus* rice var. BRRIdhan55 ($p < 0.05$; Table 3). The lowest days required for 50% flowering and maturity (50.50 and 78.33 DAT, respectively) were observed in the plants treated with N₄ (50% urea + 2 % urea spray at 30, 45 and 60 DAT) while highest days were recorded from the treatment N₃ (USG at 10 DAT) treated plots which were 52.50 and 82.50 DAT, respectively. In case of the two seedling raising methods, we observed significant variation for days to 50% flowering ($p < 0.05$; Table 4) which was 51.83 DAT in wet seed bed seedlings and 51.07 DAT in the dry seed bed seedlings. Nitrogen management and seedling raising methods had significant effect on time required for 50% flowering ($p < 0.01$; Table 5). The treatment combinations of N₄D (N₄= 50% urea + 2 % urea spray at 30, 45 and 60 DAT with dry seedbed) and N₅D (50% urea at land preparation + Magic growth spray at 30, 45 and 60 DAT with dry seedbed) required the lowest days to 50% flowering (50.33 DAT). The highest time period for 50% flowering was required in case of treatment combination N₃W (53.00 DAT). We also found significant variation in attaining maturity due to interaction between nitrogen management and seedling raising method (Table 5). N₄W required the lowest

duration for 80% maturity (78.00 DAT) and N₃W needed the longest duration (84.33 DAT). The level of nitrogen in rice field might influence the flower initiation and maturity of *T. Aus* rice. The flowering and maturity dates were significantly influenced by different N management in several studies (Rahman et al. 2016; Halder 2013 and Rahman *et al.* 2005).

Table 3. Effect of nitrogen management practices on different yield and yield contributing attributes of transplant Aus rice

Treatment	Days to 50% flowering	Days to Maturity	No. of filled grains panicle ⁻¹	No. of unfilled grains panicle ⁻¹	Panicle length (cm)	1000-seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
N ₀	51.33 b	79.67 f	55.80 f	27.40 a	19.98 f	19.98 f	2.94 f	5.07 f	8.01 f	35.32 f
N ₁	51.50 b	80.67 b	65.27 b	24.47 d	21.78 b	20.18 b	3.96 b	5.76 b	9.66 b	40.58 b
N ₂	51.83 b	80.83 c	61.70 e	25.63 b	20.62 e	20.05 e	3.38 e	5.41 e	8.78 e	38.33 e
N ₃	52.50 a	82.50 a	78.20 a	20.60 f	22.70 a	20.32 a	4.23 a	5.88 a	10.10 a	41.65 a
N ₄	50.50 d	78.33 e	62.00 d	25.23 c	21.33 d	20.12 d	3.60 d	5.53 d	9.13 d	39.32 d
N ₅	51.00 c	78.67 d	63.60 c	23.37 e	21.45 c	20.15 c	3.74 c	5.66 c	9.38 c	39.83 c
Significance level	*	*	**	**	**	*	**	**	**	**
CV (%)	2.05	2.88	7.85	8.85	5.10	3.49	8.97	7.55	7.13	3.75

Note: In a column, figures with same letter or without letter do not differ significantly as per DMRT; ‘*’ and ‘**’ = Significant at 5 and 1%, respectively ; N₀= No nitrogen, N₁=Whole urea at land preparation @ 150kg/ha, N₂=USG at LP @ 112 kg/ha, N₃= USG @ 1.8g (granule) per 4 hill (112kg/ha) at 10 DAT, N₄= 50% urea urea + 2 % urea spray at 30, 45 and 60 DAT, N₅=50% urea at land preparation + Magic growth spray at 30, 45 and 60 days. CV (%) = Percent coefficient of variation

Number of filled grains panicle⁻¹

Nitrogen management showed significant variation in the number of filled grains panicle⁻¹ ($p < 0.01$; Table 3). The highest number of filled grains panicle⁻¹ (78.20) was obtained from the N₃ i.e., USG at 10 DAT and the lowest number of filled grains panicle⁻¹ (55.80) was obtained from the no urea treated plot. This finding is in contrast with the findings of Rajarathinam and Balasubramanian, (1999) where they found application of N increased number of filled grains panicle⁻¹. The average number of filled grains panicle⁻¹ was found significantly different in seedling raising method ($p < 0.01$; Table 4). The highest number of filled grains was recorded in the wet seed bed (71.07) and lowest filled grains were in dry seed bed (57.79). Interaction effect between nitrogen management and seedling raising method had positive effect on filled grains panicle⁻¹ (Table 5). The highest number of filled grains (88.13) was obtained from N₃W i.e., when USG applied at 10 DAT in combination with the seedlings raised in wet bed and the lowest number of filled grains panicle⁻¹ (50.33) was obtained from N₀D i.e. without nitrogen in case of the seedlings raised in the dry bed. Our result suggests that highest number of grains panicle⁻¹ might be the response of enhanced availability of nitrogen from USG especially when it applied at 10 DAT. Subsequently, higher available N might results more photo assimilates and thus produced more dry matter accumulation in the panicle. These findings are also consistent with the findings of other researchers (Alam et al., 2013; Bandaogo et al., 2014; Gregory et al., 2010).

Number of unfilled grains panicle⁻¹

The number of unfilled grains per panicle was significantly different in the nitrogen management (Table 3). The maximum number of unfilled grains per panicle (27.40) was counted in case of no nitrogen and the minimum number of unfilled grains panicle (20.60) was counted in the N₃ i.e., USG at 10 DAT. Nitrogen took part both in grain formation and development and for this reason number of grains per panicle increased with adequate N levels. This result is in conformity with Halder (2013) and Nori et al., (2008). In case of seedling raising methods, number of unfilled grains per panicle was higher in wet seed bed (24.46) and minimum unfilled grains per panicle in dry seed bed (24.44; Table 4). Number of unfilled grains per panicle was found to be significantly affected by interaction effect of nitrogen management and seedling raising method (Table 5). The highest (28.73) number of unfilled grains per panicle was recorded under the N₄W that was statistically at par with N₂D (28.67) and N₀W (28.40) whereas the lowest number of unfilled grains per panicle (19.87) was counted in the treatment combination N₃W.

Panicle length (cm)

The panicle length was significantly affected by nitrogen management practices ($p < 0.01$, Table 3). The maximum panicle length (22.70 cm) was observed in USG @ 112 kg/ha at 10 DAT and the lowest (19.98 cm) panicle length was obtained from without nitrogen (N₀). The variation in panicle length due to the improved management of N was also reported by Parvin (2012). In our study, both of the seedling raising methods had significant effect on the panicle length ($p < 0.01$; Table 4) where highest length of 22.08 cm was recorded in wet seedbed compared to plants raised in dry seedbed (20.54cm). Again panicle length was also influenced significantly in case of the interaction effect of nitrogen management practices and seedling raising methods ($p < 0.05$; Table 5). The longest panicle (23.37 cm) was obtained from N₃W and the shortest panicle (19.27cm) was obtained from the N₂D which was statistically similar to N₀D (19.43cm).

Table 4. Effect of seedling raising method on yield and yield contributing attributes of transplant Aus rice

Seedling raising method	Days to 50% flowering	Days to Maturity	No. of filled grains panicle ⁻¹	No. of unfilled grains panicle ⁻¹	Panicle length (cm)	1000-seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Wet seedbed (W)	51.83	80.39 a	71.07 a	24.46 a	22.08 a	20.42 a	3.93 a	5.70 a	9.61 a	40.32 a
Dry seedbed (D)	51.07	79.83 b	57.79 b	24.44 b	20.54 b	19.84 b	3.35 b	5.41 b	8.74 b	38.02 b
Significance level	NS	*	**	**	**	*	**	*	**	**
CV (%)	2.05	2.88	7.85	8.85	5.10	3.49	8.97	7.55	7.13	3.75

Note: In a column, figures with same letter or without letter do not differ significantly as per DMRT; '*' and '**' = Significant at 5 and 1%, respectively, NS= Non-significant; CV (%) = Percent coefficient of variation

Thousand (1000)-seed weight (gm)

The effect of nitrogen management was significant in respect of 1000-grain weight of *T. Aus* rice ($p < 0.05$; Table 3). The highest 1000-grain weight (20.32 g) was obtained from the treatment N_3 and the lowest 1000-grain weight (19.98g) was found in control (N_0). This possibly happened due to the uptake of N by root of the rice plant that influenced the photosynthesis process and subsequently storage of starch in sink cell such as grain. USG provide the highest amount of available N in the field and created a chance to fill the grain properly. Hossain and Islam (2008) also reported the variation in 1000-grain weight due to the more availability of N in soil. Chaturvedi (2005) observed that N play important role in increasing protein percentage, which in turn increased the grain weight. The weight of 1000-grains was also significantly influenced ($p < 0.05$; Table 4) by the seedling raising method where the seedling raised in wet bed gave higher 1000-grain weight (20.42g) over dry bed method (19.84 g). Further, the interaction effect between nitrogen management and seedling raising method gave significant variation regarding the weight of 1000-grains ($p < 0.05$; Table 5). The treatment combination N_2W gave highest 1000-grain weight (20.63 g) which was statistically similar with N_1W , N_3W , N_4W , N_5W , N_3D , N_4D and N_5D . The lowest weight of 1000-grains (19.47 g) was obtained from N_2D

Grain yield

Grain yield was significantly influenced ($p < 0.01$) by nitrogen management practices (Table 3). By USG @ 112kg/ha at 10 DAT (N_3) produced the highest grain yield (4.23 t ha⁻¹) which was followed by the treatments N_1 , N_5 , N_4 , N_2 and N_0 . The lowest grain yield (2.94 t ha⁻¹) was recorded from without nitrogen (N_0). The highest grain yield might be due to the resultant effect of highest number of effective tillers per hill and highest number of grains per panicle as obtained in the treatment N_3 . Miah *et al.* (2006) stated that USG increased an average of 20% rice yield in tidal flooded condition. Grain yield variations due to fertilizer management were also reported by Shah *et al.* (2013), Das (2011), Jun *et al.* (2011) and Tahura (2011). Grain yield was also significantly influenced by seedling raising methods (Table 4). The highest grain yield (3.93 t ha⁻¹) was obtained from the Wet seed bed compared to the yield (3.35 t ha⁻¹) obtained by the seedlings raised in dry seed bed. Interaction between nitrogen management and seedling raising method also played positive role in promoting grain yield of transplant *Aus* rice. Highest grain yield of 4.62 t ha⁻¹ was from the treatment combination N_3W which was statistically at par with N_1W (the whole urea application at land preparation along with wet seed bed) and N_3D (USG application along with dry seed bed) and the lowest grain yield was recorded in N_0D (2.56 t ha⁻¹; Table 5).

Straw yield

Straw yield was significantly ($p < 0.01$) affected by the nitrogen management (Table 3). The highest straw yield (5.88 t ha⁻¹) was obtained from the plot applied with USG 112kg/ha at 10 DAT (N_3) and the least straw yield (5.07 t ha⁻¹) was obtained from the no urea treated plot (N_0). Availability of nitrogen at vegetative phase during the initiation of primary, secondary and tertiary tillers resulted in increased accumulation of dry matter which probably favored highest straw yield. Significant variation in straw yield was also reported by Shah *et al.* (2013) and Das (2011). Straw yield was significantly influenced ($p < 0.05$) by the seedling raising method (Table 4). The highest straw yield (5.70 t ha⁻¹) was obtained from the wet seed bed compared to (5.11 t ha⁻¹) dry seed bed. Again, the highest straw yield (6.07 t ha⁻¹) was recorded from the interaction of seedling raised in wet seed bed and

Table 5. Interaction effect of nitrogen management and seedling raising method on yield and yield contributing attributes of transplant Aus rice

Treatment combination	Days to 50% flowering	Days to Maturity	No. of filled grains panicle ⁻¹	No. of unfilled grains panicle ⁻¹	Panicle length (cm)	1000-seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
N ₀ W	51.67 ab	79.67 bc	61.27 c	28.40 a	20.53 b	20.17 ab	3.32 bc	5.25 bc	8.57 bc	36.23 bc
N ₁ W	51.67 ab	80.33 ab	77.07 b	22.73 bc	22.80 ab	20.37 ab	4.24 ab	5.91 ab	10.13 ab	41.77 ab
N ₂ W	52.33 ab	81.67 ab	63.80 bc	22.60 bc	21.97 ab	20.63 a	3.77 bc	5.66 b	9.42 ab	39.93 bc
N ₃ W	53.00 a	84.33 a	88.13 a	19.87 c	23.37 a	20.50 ab	4.62 a	6.07 a	10.67 a	43.17 a
N ₄ W	50.67 bc	78.00 c	66.13 bc	28.73 a	21.80 ab	20.47 ab	3.78 bc	5.60 b	9.38 ab	40.23 b
N ₅ W	51.67 ab	78.33 bc	70.00	24.40 b	22.03 ab	20.40 ab	3.85 bc	5.68 b	9.50 ab	40.60 ab
N ₀ D	51.00 b	79.67 bc	50.33 d	26.40 ab	19.43 c	19.80 bc	2.56 c	4.89 c	7.45 c	34.40 c
N ₁ D	51.33 ab	81.00 ab	53.47 cd	26.20 ab	20.77 b	20.00 b	3.67 b	5.61 b	9.18 b	39.40 bc
N ₂ D	51.33 ab	80.00 b	59.60 cd	28.67 a	19.27 c	19.47 c	2.99 bc	5.15 bc	8.14 bc	36.73 bc
N ₃ D	52.00 ab	80.67 bc	68.27 bc	21.33 bc	22.03 ab	20.13 ab	3.83 ab	5.70 ab	9.53 ab	40.13 b
N ₄ D	50.33 c	78.67 bc	57.87 cd	21.73 bc	20.87 ab	19.77 bc	3.42 bc	5.46 bc	8.88 bc	38.40 bc
N ₅ D	50.33 c	79.00 bc	57.20 cd	22.33 bc	20.87ab	19.90 bc	3.62 b	5.64 b	9.26 b	39.07 bc
Significance level	**	*	**	**	*	*	**	**	**	**
CV (%)	2.05	2.88	7.85	8.03	5.10	3.49	8.97	7.55	7.13	3.75

Note: In a column, figures with same letter or without letter do not differ significantly as per DMRT; '*' and '**' = Significant at 5 and 1%, respectively and NS= Not significant; N₀= No nitrogen, N₁=Whole urea at land preparation @ 150kg/ha, N₂=USG at LP @ 112 kg/ha, N₃= USG @ 1.8g (granule) per 4 hill (112kg/ha) at 10 DAT, N₄= 50% urea + 2 % urea spray at 30, 45 and 60 DAT, N₅= 50% urea at land preparation + Magic growth spray at 30, 45 and 60 days. W=wet seed bed and D=Dry seed bed; CV (%) = Percent coefficient of variation

112kg/ha USG at 10 DAT i.e., N₃W (p<0.01) which was statistically similar with N₁W (5.91 t ha⁻¹) and N₃D (5.70 t ha⁻¹). The lowest straw yield (4.89 t ha⁻¹) was recorded in N₀D (Table 5).

Biological yield

Significantly highest (p<0.01) biological yield (10.10 t ha⁻¹) was found from USG 112kg/ha at 10 DAT (N₃) and the lowest value (8.01 t ha⁻¹) regarding biological yield was found from the no urea treated plot (N₀; Table 3). Biological yield was significantly influenced by seedling raising method (Table 4) where the maximum biological yield (9.61 t ha⁻¹) was found in case of wet seed bed and the lowest biological yield (8.74 t ha⁻¹) was found from dry seed bed. Interaction effect between nitrogen management and seedling raising method was significant in respect of biological yield (Table 5). The highest biological yield (10.67 t ha⁻¹) was recorded in N₃W treatment combination which was statistically at par with the treatment combinations N₁W, N₂W, N₄W, N₅W and N₃D and the lowest biological yield (7.45 t ha⁻¹) in the N₀D.

Harvest index

Nitrogen management produced significant differences (p<0.01) in respect of harvest index (Table 3). The highest harvest index (41.65) was found from the N₃ treatment and the lowest harvest index (35.32) was found from the control (N₀). Harvest index was also significantly influenced (p<0.01) by the seedling raising method (Table 4). Higher harvest index (40.32) was found from the wet seed bed compared to dry seed bed (38.02). In considering the interaction effect, nitrogen management and seedling raising method significantly highest harvest index (43.17) was recorded in the N₃W (p<0.01) which was statistically similar with the treatment combinations of N₁W and N₅W. The lowest harvest index (34.40) was observed in case of N₀D (Table 5)

Conclusions

The study concludes that seedlings raised in wet seedbed produced highest grain yield with the application of USG at 10 DAT and this was statistically similar to the whole urea application at land preparation along with wet seed bed and USG application along with dry seed bed. This suggests that wet seed bed preparation with whole urea application at land preparation or dry seed bed preparation with USG application at 10 DAT may be practiced for cost saving in tidal ecosystem of Bangladesh to avoid the complexity of USG application and scarcity of water for wet seed bed preparation.

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