Assessing the Effect of Seedling Age and Time of Urea Supergranule Application on Rice Growth, Yield and Nitrogen Use efficiency

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Abstract

Nitrogen is the most limiting nutrient in tropical soils and nitrogen fertilizer application to rice is subject to losses. Good synchrony of nitrogen availability to crop's need is a strategy to reduce losses and improve efficiency. A pot experiment was conducted to assess the effect of seedling age and time of urea supergranule application on rice growth, yield and nitrogen use efficiency. The experiment consisted of 10, 14, 21 and 28-day old seedlings and urea supergranule applied at 0, 7, 14 and 21 days after transplanting with a check treatment without nitrogen application. Results indicated significant effect of seedling age on growth, yield and nitrogen use efficiency. Highest grain yield, nitrogen uptake, agronomic use efficiency of nitrogen and nitrogen recovery efficiency were obtained with 10 and 14-day old seedlings, while the lowest values were observed for 28-day old seedlings. Urea supergranule applied at 7 or 14 days after transplanting gave the highest rice growth parameters while the lowest performances were obtained with urea supergranule applied at 0 and 21 days after transplanting. The interactive effect showed better growth, yield and nitrogen use efficiency of rice when urea supergranule was applied at 7 or 14 days after transplanting seedlings of 10 and 14-day old. The results suggested that even though application of urea supergranule at 7 and 14 days after transplanting increased rice yield over 0 and 21 days after transplanting, for the aged seedlings of 21 and 28-day old, the variation of urea supergranule application time could not compensate for the decrease of yield due to old seedlings transplanting.

Introduction

Rice (*Oryza sativa, L.*) is a staple food for more than 50% of the world's population (Zhao et al., 2011) and largely contributes to food security (Dass and Chandra, 2013). Rice demand increases each year with increase in world's population. This increasing demand can only be met by increasing rice production through the expansion of cultivated areas and appropriate management of production factors. Among the various factors responsible for optimizing growth and yield of rice are age of seedlings at transplanting and time of nitrogen (N) application. Shen et al. (2006) stated that transplanting at the appropriate seedling age followed by the application of fertilizer is the most important crop management that enhances rice performance.

Appropriate time of N supply to rice is a key factor for increasing rice yield. According to Appel (1994), application time is important for good synchrony between rice demand of N and its fertilizer supply throughout the cropping season. The conventional strategy for synchronizing N supply to rice need, minimizing N losses and increasing rice yield and N-fertilizer use efficiency is to split the total required N into two or three applications (Moletti et al., 1992; Dobermann and Fairhurst, 2000). However, because of flooding and adverse soil-water conditions prevailing in irrigated rice system, split application of N fertilizer does not always result in increased N uptake (Mohanty et al., 1999). Alternatively, deep application of urea supergranule (USG) is reported to reduce N losses in paddy soil and allow continuous N availability along the rice growing season and therefore improves rice yield components and yields over split application of prilled urea (Savant and Stangel, 1990). In USG technology, the fertilizer is applied once during the cropping season contrarily to the conventional urea that requires 2 to 3 or more applications (Rahman and Barmon, 2015). Much is known about the application time of conventional urea (Craswell et al., 1981; Kundu and Ladha, 1995; Nyampinga et al., 2011) but few works have targeted the time of USG application on transplanted rice (Craswell et al., 1981; Abedin et al., 2015). In general, USG is recommended to be applied 7 days (Savant and Stangel, 1990) or 10 days after rice transplant. But these recommendations have not taken into consideration factors such as soil type, water regime or age of seedlings at transplanting which are also important for good synchrony of N supply.

Seedling age is rated high in rice cultivation because it has tremendous effect on rice growth and yield characters such as plant height, tiller production, panicle length, and grain formation (Ali et al., 1995). Many researchers have demonstrated that the achievement of high grain yield of rice requires an optimal age of seedlings (Alam et al., 2002; Mobasser et al., 2007; Mishra and Salokhe, 2008). Mishra and Salokhe (2008) observed greater root growth and establishment while transplanting younger seedlings than old ones. Himeda (1994) and Sasaki (2004) explained that the above and below-ground characteristics of rice plant, before and after transplanting, vary with age of seedlings. Research indicated that higher rice yields were obtained in transplanting young seedlings than aged seedlings (Thanunathan and Sivasubramanian, 2002; Mobasser et al., 2007 and Sarwar et al., 2011). Furthermore, Rasool et al. (2016) indicated that transplanting aged seedlings can lead to poor crop performance. In the system of rice intensification (SRI), Patra and Haque (2011) reported higher number of tillers with 10-day old seedlings compared to 12, 14 and 16-day old seedlings. Makarim et al. (2002) also indicated in the SRI that rice yield components and yield can be increased by transplanting seedlings as young as 14 days instead of older seedlings of 21-23 days.

Based on the above findings, young rice seedlings could be recommended for optimum rice performance. However, management of very young seedlings by hand transplant is very difficult for farmers who always delay seedlings on nursery beds. Accordingly, judicious management of the USG application time could compensate for the negative effect of aged seedling on rice performances. Furthermore, early (7-10 days after transplanting) application of urea fertilizer to rice can induce ammonium toxicity (Haden et al., 2011) and negatively impact on rice growth and yield (Manickam and Ramaswami, 1985). Thus, for optimum rice yield, there is the need to determine the appropriate application time of USG and the age of rice seedlings to be transplanted. Therefore, the objective of this study was to evaluate the effect of seedling age and USG application time on the growth, yield and nitrogen use efficiency of rice.

Materials and methods

Soil sample used

A pot experiment was conducted in a screen house at Kovie in Togo. The soil used is clayey with 11% sand, 16% silt and 73% clay. The soil was slightly acid (pH 5.6) containing 1.9% organic carbon, 0.29% total nitrogen, 32.1 mg kg^{-1} available phosphorus and CEC of 27.3 cmol(+) kg^{-1}.

Treatments, experimental design and management

Two factors were studied: the seedling age (10, 14, 21 and 28-day old) and the USG application time (0, 7, 14 and 21 days after transplanting (DAT)). A control treatment without N-fertilizer application was included (Table 1). The experiment was laid out in a complete randomized design with three replications. Rice variety IR-841 with cycle duration of 120 to 130 days (IRRI, 1973) was used. Experimental pots were filled with 30 kg of soil, flooded with water three days before transplanting 10, 14, 21 and 28 day old rice seedlings. Each pot received four hills of seedlings at a spacing of 20 cm x 20 cm. A 0.84 g of triple super phosphate (TSP) and 0.77 g of muriate of potash (MOP) were applied to each pot as basal fertilizers based on fertilizer recommendation rates for rice in Togo. For USG application, a granule of 1.8 g was placed per pot between the 4 hills of rice at a depth of 8cm.

TABLE 1
Treatments formulation

Treatment	Description
D_{10} 0	10 days age seedling + No USG
D_{10} DAT_0	10 days age seedling + USG at 0 DAT
D_{10} DAT_7	10 days age seedling + USG at 7 DAT
D_{10} DAT_{14}	10 days age seedling + USG at 14 DAT
D_{10} DAT_{21}	10 days age seedling + USG at 21 DAT
D_{14} 0	14 days age seedling + No USG
D_{14} DAT_0	14 days age seedling + USG at 0 DAT
D_{14} DAT_7	14 days age seedling + USG at 7 DAT
D_{14} DAT_{14}	14 days age seedling + USG at 14 DAT
D_{14} DAT_{21}	14 days age seedling + USG at 21 DAT
D_{21} 0	21 days age seedling + No USG
D_{21} DAT_0	21 days age seedling + USG at 0 DAT
D_{21} DAT_7	21 days age seedling + USG at 7 DAT
D_{21} DAT_{14}	21 days age seedling + USG at 14 DAT
D_{21} DAT_{21}	21 days age seedling + USG at 21 DAT
D_{28} 0	28 days age seedling + No USG
D_{28} DAT_0	28 days age seedling + USG at 0 DAT
D_{28} DAT_7	28 days age seedling + USG at 7 DAT
D_{28} DAT_{14}	28 days age seedling + USG at 14 DAT
D_{28} DAT_{21}	28 days age seedling + USG at 21 DAT

DX = Seedling of X-day old, DATX = X Days after transplanting

Data collection

Plant height was measured at active tillering (45 DAT), flowering (75 DAT) and at harvest. The number of tillers, length of panicles, weight of 1000-grain, and grain and straw yields were determined at harvest. Rice straw and grain were sampled, oven dried and their N concentrations were determined. Nitrogen use efficiency was evaluated as the agronomic use efficiency of N (AE), the physiological efficiency (PE), and the N recovery efficiency (RE) which were calculated as documented by

$$AE = \frac{GY_N - GY_0}{N_r} \quad [\text{eq. } 1];$$

$$PE = \frac{BY_N - BY_0}{U_N - U_{N0}} \quad [\text{eq. } 2];$$

$$\%RE = \frac{U_N - U_{N0}}{N_r} \times 100 \quad [\text{eq. } 3]$$

Dobermann (2005)

Where N_r is the rate of N applied (g pot^{-1}), GY_N and GY_0 are the rice grain yield with and without N application (g pot^{-1}) respectively, BY_N and BY_0 are the total biomass yields (Grain + straw) with and without N application respectively, and U_N and U_{N0} are the rice N uptakes with and without N application (g pot^{-1}) respectively.

Statistical analysis was run with GenStat software (12th Edition, 2009). Data was subjected to analysis of variance at 5% probability level. Means were compared using protected LSD test (5%).

Results

Growth characteristics

Plant height

The effect of seedling age on rice plant height at active tillering stage (45 DAT), flowering stage (75 DAT) and at harvest is shown in Fig. 1. Results showed significant ($p < 0.05$) decrease in plant height with increasing age of the seedling at the different growth stages (Fig. 1a). At 45 and 75 DAT, the tallest rice plants were observed with 10 and 14-day old seedlings but at maturity stage, the tallest rice plant was obtained with 10-day old seedlings. At all growth stages the lowest rice plant height was observed with 28-day old seedlings.

The USG application time significantly ($p < 0.05$) affected the plant height. At the 45, 75 DAT and at maturity, the lowest plant height was recorded with the control treatment (without N application; Fig. 1b). With the USG treatments, at 45 and 75 DAT, the tallest rice plant was observed when USG was applied at 7 DAT, followed by 14 DAT treatment. The 0 and 21 DAT treatments showed similar heights at the tillering stage while at flowering stage, 0 DAT treatment showed higher value when compared to the 21 DAT treatment. At maturity, 7 and 14 DAT treatments showed similar plant heights which were the tallest

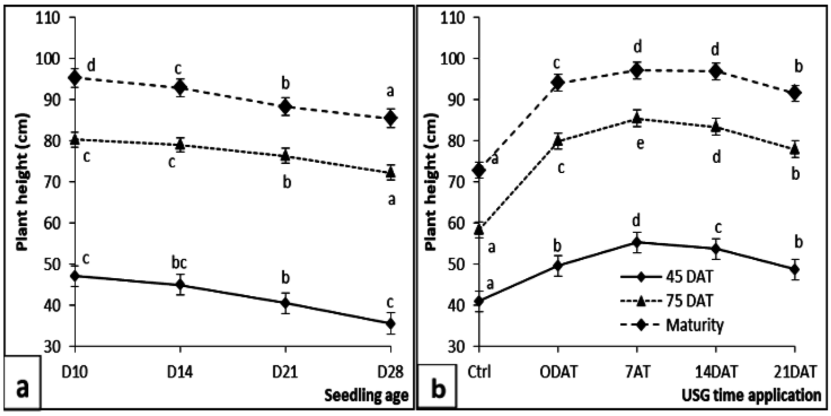

Figure 1 Rice plant height as affected by seedling age (a) and time of USG application (b).
Points with same alphabets are statistically similar

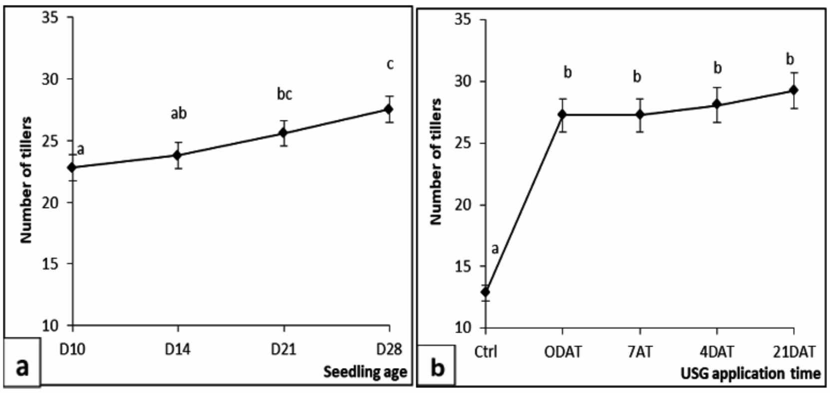

Figure 2 Number of tillers as affected by seedling age (a) and time of USG application (b).
Points with same alphabets are statistically similar

and followed by the 0 DAT treatment (Fig. 1 b).

Number of tillers

The total number of tillers was significantly ($p < 0.05$) affected by seedling age (Fig. 2). The highest number of tillers (27) was recorded with 21 and 28-day old seedlings while the lowest number of tillers (23) was observed with 10-day old seedlings (Fig. 2a). However, similar number of tillers was observed for 14 and 21-day old seedlings. There was an increase in number of tillers when USG was applied, however, there was no significant ($p > 0.05$) difference in time of USG application (Fig. 2b).

Interaction effect on plant height and number of tillers

The interaction effect between the age of rice seedlings and the time of USG application on the height was not significant ($p > 0.05$) at 45 DAT and at maturity. However, at 75 DAT, the interaction showed significant ($p < 0.05$) effect. At this growth stage, the highest plant height (85-87 cm) was obtained for 10 and 14-day old seedlings when USG was applied at 7 or 14 DAT. The lowest height was obtained for the 28-day old seedlings when USG was applied at the 21 DAT. At maturity, the 10 and 14-day old seedlings each combined with USG applied at 7 or 14 DAT maintained the highest height (99-101 cm). However, the differences were not significant ($p > 0.05$) among the interactions. The total number of tillers was not affected by the interaction between the seedling age and the time of USG application

TABLE 2

Interaction effect of seedling age and time of USG application on plant height and tillers

Treatment	Height (cm)			Number of tillers per pot
	45DAT	75 DAT	Maturity	
10DAT*Ctl	42.3	62.9 c	76.7	13
10DAT*0	47.4	84.2 ij	99.7	30
10DAT*7	49.3	80.8 fgh	101.1	30
10DAT*14	50.1	86.7 jk	101.2	29
10DAT*21	46.0	80.8 fgh	98	25
14DAT*Ctl	38.8	59.3 b	75	15
14DAT*0	43.6	80.9 gh	96	29
14DAT*7	48.9	87.5 k	98.9	32
14DAT*14	48.2	85.2 ijk	100.6	31
14DAT*21	45.0	82.8 hi	94	31
21DAT*Ctl	34.7	57.3 b	72	12
21DAT*0	40.1	78.8 efg	91.8	27
21DAT*7	44.2	84.3 ij	95.2	28
21DAT*14	43.2	83.13 hi	93.7	28
21DAT*21	40.0	77.9 ef	88.7	24
28DAT*Ctl	29.6	53.5 a	67.3	11
28DAT*0	36.1	75.8 e	89	23
28DAT*7	40.5	82.7 hi	93.3	26
28DAT*14	37.7	78.8 efg	92	25
28DAT*21	33.4	70.1 d	85.5	29
Fpr	0.035	0.031	0.291	0.291
LSD	2.319	3.04	NS	NS
CV	2.8	2.4	2.7	12

Fpr= Fisher probability, NS = Not Significant, LSD = Least Significant Difference, CV = Coefficient of Variation

(Table 2).

Yield components, yield and harvest index

Length of panicles

The age of rice seedlings significantly ($p < 0.05$) affected the length of panicle (Fig. 3). The length of panicle increased from 10-day old seedling to 14-day old seedling, however, the two panicle lengths were not significantly ($p > 0.05$) different (Fig. 3a). The panicle length then decreased from 14-day old to 28-day old seedling. There was no significant ($p > 0.05$) difference between 21- and 28-day old seedlings. Application of USG significantly ($p < 0.05$) increased panicle length, however, time of application did not affect panicle length (Fig. 3b).

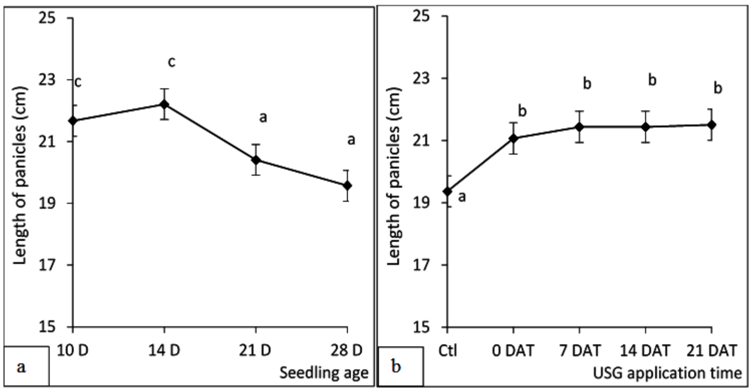

Figure 3 Length of panicles as affected by seedling age (a) and time of USG application (b). *Points with same alphabets are statistically similar*

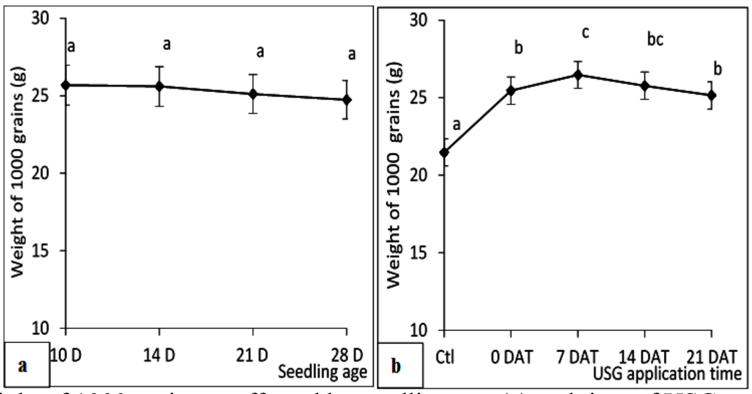

Figure 4 Weight of 1000 grains as affected by seedling age (a) and time of USG application (b). *Points with same alphabets are statistically similar*

Weight of 1000 grains

The seedling age did not affect the weight of 1000 grains (Fig. 4 a). However, the weight of 1000 grains was significantly ($p < 0.05$) affected by the time of USG application. The application of USG sharply increased grain weight. The highest 1000 grain weight (26 g) was obtained when USG was applied at 7 and 14 DAT. However, application of USG at 0, 14 and 21 DAT produced similar weight (25 g) (Fig. 4 b).

Grain yield

The grain yield significantly ($p < 0.05$) decreased with seedling age (Fig 5a). The highest average grain yield (86 g pot^{-1}) was obtained with 10 and 14-day old seedlings followed by 21-day old seedlings. The 28-day seedlings had the lowest grain yield (72 g pot^{-1}). The grain yield was also significantly ($p < 0.05$) affected by the time of USG application (Fig. 5b). Rice yield increased with increasing time of USG application from 0 to 14 DAT. Thereafter, it decreased when USG application time was increased from 14 to 21 DAT. Similar grain yields (95 g pot^{-1}) were obtained when USG was applied at 7 and 14 DAT. Application of USG at 0 DAT gave the lowest grain yield (87 g pot^{-1}) as compared with other USG treatments.

Relationship between the rice grain yield and the seedling age, the grain yield and USG application time

The equations in terms of rice grain yield as a function of the seedling age and time of USG application are shown in Fig. 6. Knowing the age of seedling (in days) and the time of USG application (in days after transplanting), the rice grain yield can be predicted with the following equations:

$$GY_{(Grain\ yield)} = -0.036\ D^2 + 0.5715\ D + 84.168 \quad R^2 = 0.930 \quad \text{[Eq 4]}$$

$$GY_{(Grain\ yield)} = -0.0701\ DAT^2 + 1.5666\ DAT + 86.737 \quad R^2 = 0.993 \quad \text{[Eq 5]}$$

Where: GY = grain yield

D = Age (in days) of the seedling

DAT = Number of days after transplanting

Straw yield and harvest index

The straw yield significantly (p < 0.05) decreased with the age of the seedlings (Fig. 7a). The highest performance (94 g pot^{-1} on average) was obtained with 10 and 14-day old seedlings. The 21 and 28-day old seedlings produced similar but lowest straw yields. The time of USG application affected the straw yield. Application of USG at 0 DAT produced the lowest straw yield (97 g pot^{-1}) as compared with the other USG treatments. The highest straw yield was recorded with USG applied at 7 and 14 DAT (Fig. 7 b). No significant (*p > 0.05*) effects of the seedling age and time of USG application were observed for harvest

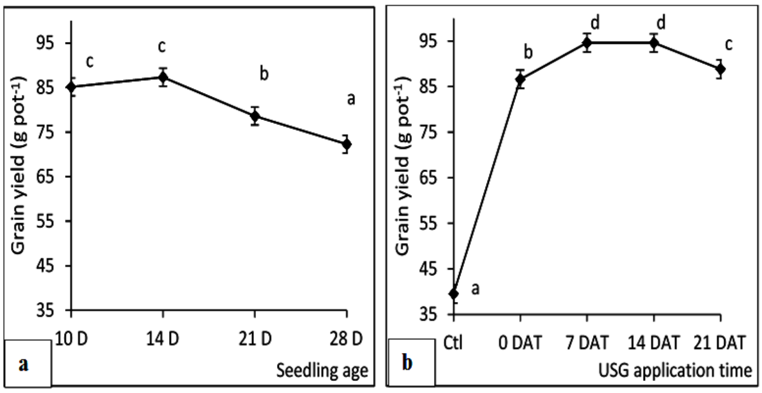

Figure 5 Grain yield as affected by increasing age of seedlings (a) and time of USG application (b). *Points with same alphabets are statistically similar*

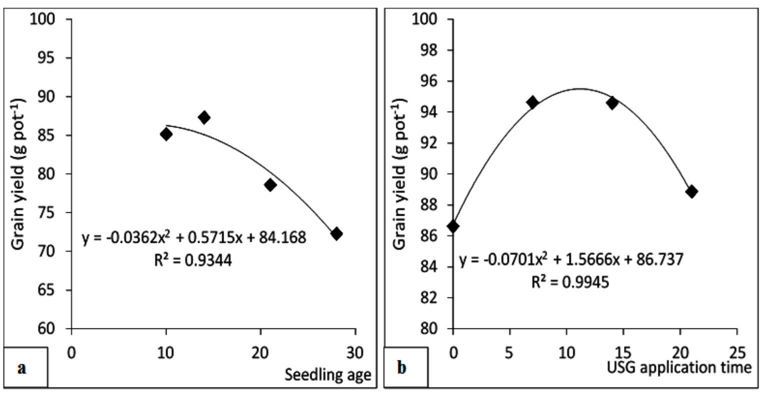

Figure 6 Relationship between the grain yield and the seedling age (a) and rice yield and time of USG application (b) *Points with same alphabets are statistically similar*

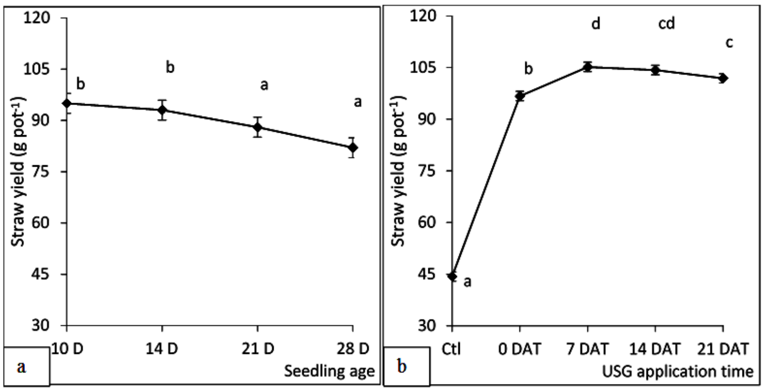

Figure 7 Straw yield as affected by increasing age of seedling (a) and time of USG application (b). *Points with same alphabets are statistically similar*

TABLE 3
Interaction effect of seedling age and time of USG application on rice growth and yield parameters

Interaction	Length of panicles (cm)	Weight of 1000 grains (g)	Grain Yield (g pot^{-1})	Straw Yield (g pot^{-1})	Harvest Index
10D*Ctl	19.9	22.6	44.27 c	51	46
10D*0 DAT	21.67	25.4	89.80 ghi	99	48
10D*7DAT	22.03	26.2	96.97 k	108	47
10D*14DAT	22.1	25.6	99.23 klm	108	48
10D*21DAT	22.67	25.1	95.53 jk	108	47
14D*Ctl	20.17	20.0	42.97 c	48	47
14D*0DAT	21.77	26.0	93.00 ij	98	47
14D*7DAT	23.5	27.4	102.10 m	107	48
14D*14DAT	23.43	27.4	100.73 lm	107	48
14D*1 DAT	22.2	26.7	97.77 kl	105	47
21D*Ctl	19.03	21.9	39.10 b	44	47
21D*0DAT	20.97	25.6	84.03 f	92	48
21D*7DAT	20.37	26.3	91.67 i	101	48
21D*14DAT	20.67	25.2	90.97 hi	102	47
21D*21DAT	21.03	24.8	87.20 fg	99	47
28D*Ctl	18.37	21.4	31.75 a	35	48
28D*0	19.9	24.8	79.63 e	88	47
28D*7DAT	19.87	26.0	87.73 fgh	97	47
28D*14DAT	19.57	24.9	87.43 fgh	97	47
28D*21DAT	20.13	24.0	74.93 d	91	45
Fpr	0.853	0.119	0.626	0.365	0.288
LSD	*NS*	*NS*	3.76	*NS*	*NS*
CV	5.8	4.7	2.8	3.6	1.8

Fpr= Fisher probability, NS = Not Significant, LSD = Least Significant Difference
CV = Coefficient of Variation

index.

Interaction effects of the seedling age and time of USG application on rice yield components and yield

The interaction between the seedling age and the time of USG application significantly ($p < 0.05$) affected the grain yield (Table 3). The highest grain yields were obtained when 14-day old seedlings were transplanted and USG

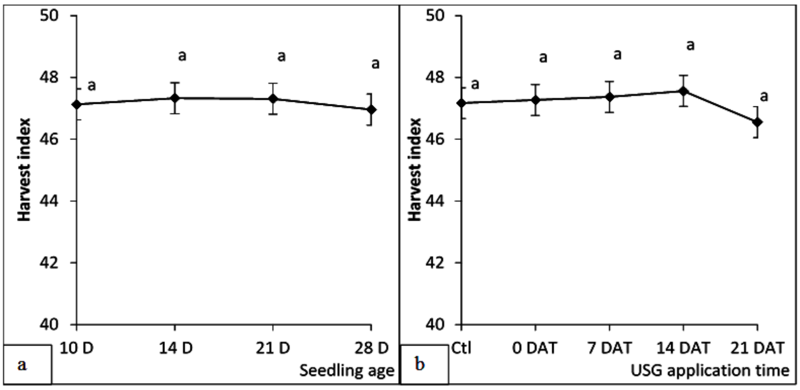

Figure 8 Harvest Index as affected by increasing age of seedling (a) and time of USG application (b) *Points with same alphabets are statistically similar*

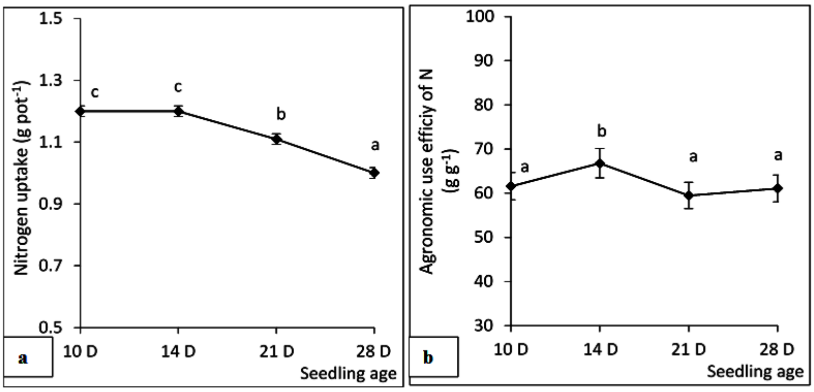

Figure 9 Effect of seedling age on NU (a) and AE (b)*Points with same alphabets are statistically similar*

was applied either at 7 or 14 DAT. The lowest grain yield was observed with the 28-day old seedlings with USG application at 21 DAT. With the 21-day and 28-day old seedlings, the variation of USG application time could not increase rice yield up to the highest obtained with 10 and 14-day old seedlings. This suggests that rice yield decreased due to transplanting of aged seedlings, and could be compensated for by varying USG application time. No significant ($p > 0.05$) interaction effect between the seedling age and the time of USG deep placement was observed for length of panicles, weight of 1000 grains, straw yield and harvest index (Table 3).

Nitrogen uptake and nitrogen use efficiency

The nitrogen uptake (NU) decreased with increasing age of the seedlings (Fig. 9a). The NU was lowest (1 g pot^{-1}) with the oldest seedlings (28-day old) while the highest NU (1.2 g pot^{-1}) was observed for 10 and 14-day old seedlings. There was significant ($p < 0.05$) difference between 28-day old and other

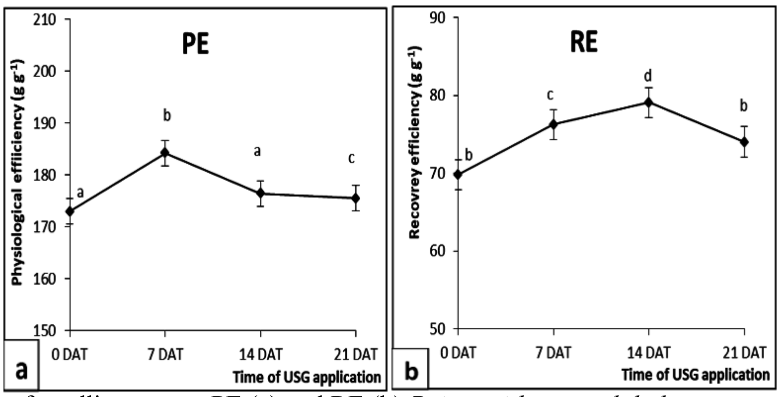

Figure 10 Effect of seedling age on PE (a) and RE (b) *Points with same alphabets are statistically similar*

treatments.

The agronomic efficiency (AE) increased with the seedling age from 10-day old seedlings to reach a peak (67 g g-1) with 14-day old seedlings (Fig. 9 b). Thereafter, it decreased when the seedling age increased to 21 and 28-day old with similar performances (60 g g^{-1} on average). On the contrary, the physiological efficiency (PE) increased with increasing seedling age (Fig. 10a). The highest PE was obtained with the oldest seedlings (28-day old) while the lowest was observed with the young seedlings (10-day old). The recovery DAT where it reached a maximum value (1.29 g pot^{-1}) and decreased thereafter when the application time of USG increased to 21 DAT. The highest AE was obtained when the USG was applied at 7 or 14 DAT (Fig. 11b). The 0 DAT treatment recorded the lowest AE. The highest PE (184 g g^{-1}) was obtained when USG was applied at 7 DAT (Fig. 12a). Statistically, the PE obtained for USG applied at 0, 14 and 21 DAT were similar but lower than that of 7 DAT (Fig. 12 a). The RE significantly ($p < 0.05$) increased with increasing time of USG application up to 14 DAT, which recorded the

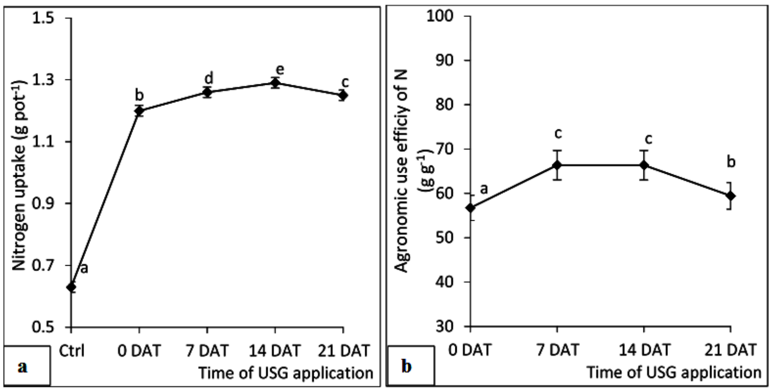

Figure 11 Effect of time of USG application on NU (a) and AE (b) *Points with same alphabets are statistically similar*

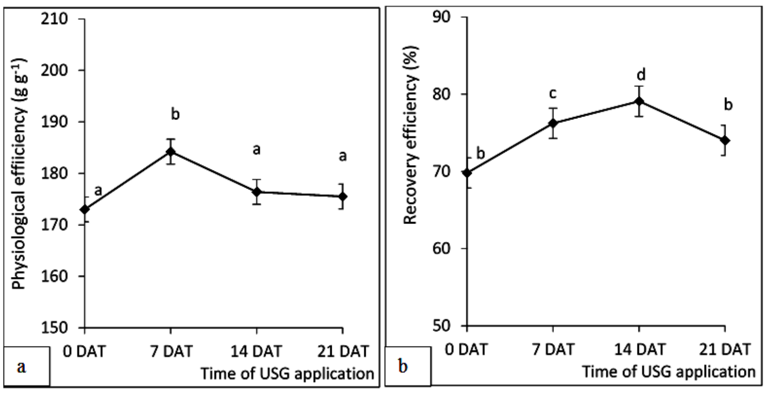

Figure 12 Effect of Time of USG application on PE (a) and RE (b) *Points with same alphabets are statistically similar*

efficiency (RE) was similar for 10 and 14-day old seedlings but higher than those obtained with 21 and 28-day seedlings which were also similar (Fig. 10b).

Differences were observed in the nitrogen uptake (NU) with regard to the age of rice seedlings and time of USG application (Fig. 11a). The NU increased from 0 DAT to 14

maximum value (79%). The RE decreased thereafter when the USG application time was delayed from 14 to 21 DAT (Fig. 12 b).

The interaction effects of the seedling age and the time of USG application on the NU and NUE

The interaction between seedling age and time of USG application showed significant effects on the NU and AE (Table 4). The highest NU (1.3 g pot^{-1}) was obtained with 10 and 14-day old seedlings when the USG was applied either at 7, 14 or 21 DAT. The lowest NU was observed with 28-day old seedlings when USG was applied at 0 DAT or 21 DAT.

The AE was highest with the 14-day old seedlings when USG was applied at the 7 and 14 DAT. The interaction was least with the 28-day seedlings combined with USG application at 21 DAT. The interaction between the seedling age and the time of urea application did not significantly ($p>0.05$) affect the PE and RE (Table 4).

Discussion

Effect of seedling age on rice growth, yield, NU and AUE of N

In general, rice plant height decreased with increasing age of seedlings at all growth stages. Essentially, transplanting young rice seedlings reduces the transplanting shock and favours early root establishment and growth in the soil as indicated by Rahman et al. (2013), Kirttania et al. (2013) and Rasool et al. (2016). Also, young seedlings tend to exploit the initial vigour of the genotype which provides initial conditions for better establishment of the crop (Vishwakarma et al. (2016).

The number of tillers increased with increasing age of seedlings. This result is in agreement with Kewat et al. (2002) and Rasool et al. (2016) who reported lower rice tillering with young seedlings than old ones. Sarkar et al. (2011) found that transplanting 35-day old seedlings produced significantly greater tillers as compared with 25-day old seedlings. The result of this study could be explained by

TABLE 4

Interaction effect of the seedling age and time of USG application on NU and NUE

Interaction	NU (g pot^{-1})	AUE (g g^{-1})	PE (g g^{-1})	% RE
10DAT*Ctl	0.68 b	-	-	-
10DAT*0	1.27 ghi	54 ab	159	71
10DAT*7	1.34 jk	63 def	170	80
10DAT*14	1.37 k	66 efg	162	84
10DAT*21	1.36 jk	61 cd	160	82
14DAT*Ctl	0.66 b	-	-	-
14DAT*0	1.31 hij	60 cd	168	78
14DAT*7	1.33 ijk	71 h	185	81
14DAT*14	1.37 k	69 gh	170	85
14DAT*21	1.33 jk	66 efg	174	81
21DAT*Ctl	0.64 b	-	-	-
21DAT*0	1.19 def	54 ab	170	67
21DAT*7	1.25 fgh	63 def	181	73
21DAT*14	1.24 fg	62 de	184	72
21DAT*21	1.22 efg	57 bc	178	70
28DAT*Ctl	0.55 a	-	-	-
28DAT*0	1.08 c	57 bc	194	64
28DAT*7	1.14 d	67 fgh	200	71
28DAT*14	1.17 de	67 fgh	189	75
28DAT*21	1.071 c	52 a	190	63
Fpr	<.001	<.001	0.380	0.054
LSD	0.061	4.2	*NS*	*NS*
CV	3.3	3.1	3.8	3.2

Fpr= Fisher probability, NS = Not Significant, LSD = Least Significant Difference, CV = Coefficient of Variation

TABLE 5
Regression analysis between grain yield and NU and NUE

Parameter	Estimate	SE	t pr.
Constant	1.7	10.8	0.879
AE	0.725	0.127	<.001
PE	-0.0533	0.0455	0.248
RE	-0.236	0.13	0.077
NU	57.13	5.55	<.001
R^2		93.7	
Pr		<.001	

TABLE 5
Result of regression analysis between grain yield and NU and AE

Parameter	Estimate	SE	t pr.
Constant	-7.8	3.82	0.047
AE	0.532	0.053	<.001
NU	52.62	3.02	<.001
R^2		93.7	
Pr		<.001	

the continuous rice tillering at maturity as observed in pots that received old seedlings. However, in the System of Rice Intensification (SRI), Patra and Haque (2011) reported higher number of tillers with 10-day old seedlings compared to 12, 14 and 16-day old seedlings.

The length of panicles decreased with increasing seedling age. This result is in conformity with Prabha et al. (2011), Kirttania et al. (2013) and Rahimpour et al. (2013) who reported that the age of rice seedlings at transplanting significantly influences the length of panicles. This result could be as a consequence of greater growth rate observed with young transplanted seedlings as compared with old ones.

The seedling age did not affect the weight of 1000 grains and may be due to the fact that 1000 grain weight hardly varies with cultural practices since the weight of 1000 grains depends largely on genetic makeup of the crop variety and is therefore least affected by growing condition (Ashraf et al., 1999). Rice grain and straw yields decreased with increasing age of seedling age and that can be attributed to the higher rice growth observed with younger seedlings. Young seedlings may not have suffered from damage of the roots during uprooting and transplanting and as result; the root establishment is faster and hence there is a better vegetative growth (Ros et al., 2003). Similarly, transplanting of younger seedlings along with soil keep the roots intact resulting in their early adaptation to soil and climatic condition, thereby inducing better growth and yield (Uphoff, 2002). Ali et al. (1995) indicated that young seedlings have tremendous effect on rice growth and yield characters such as plant height, tiller production, panicle length, and grain formation. Studies at SRI also showed that rice yield components and yield can be increased by transplanting seedlings as young as 14 days instead of older seedlings of 21-23 days (Makarim et al., 2002). The increase in the number of tillers observed in the present study with aged seedlings did not contribute to increase in grain yield since late production of many tillers near the maturity stage did not produce panicles that develop into grains. Hanada (1979) indicated that many of the late tillers do not produce panicles due to higher population and nutrients competition.

The nitrogen uptake (NU) markedly decreased with seedling age. This result confirms the finding of Rasool et al. (2016) who obtained higher NU for 35 days seedlings than those of 45-day old. As a result of increased NU with young seedlings over old ones, the physiological efficiency (PE; being inverse function of NU) was higher for aged seedlings as compared to young ones while the recovery efficiency (RE) was higher with the young seedlings than with old ones. Salem et al. (2011) reported high NU and RE for young seedlings.

Effect of USG application time on rice growth, yield, NU and AUE of N

The highest plant height, weight of 1000 grains, grain and straw yields were recorded when USG was applied at 7 or 14 DAT. This could be attributed to a good synchrony of N availability to rice need during its growing cycle. Nitrogen synchrony to rice plant need is the main objective for the use of USG. With USG deep placement, the released NH_4^+ following urea hydrolysis is adsorbed on soil particles and released slowly for rice root uptake throughout the growing season (Savant and Stangel, 1990). This makes the USG to be considered as a slow release N-fertilizer although it dissolves some few hours after deep placement.

Application of USG at 0 DAT showed the lowest rice growth, yield, NU and NUE performances. This could be attributed to a lag phase of the USG-N to diffuse and become available to young rice plants that also take one to two weeks for root establishment and development (Savant and Stangel, 1990). Also, the toxicity effect of early ammonium-N fertilizer application can affect rice performances (Gaudin, 1988). Bremner (1995) and Fan and MacKenzie (1995) observed ammonia toxicity on rice plant when urea fertilizer was applied to young rice plants. The rice yield, NU and NUE performances when USG was applied at 21 DAT were lower than 7 and 14 DAT indicating a late supply of N to the rice plant. The application at 21 DAT might have delayed N availability to rice and therefore induced irreversible impacts on its growth and yield. The importance of early rice N fertilization was proven in many studies (Keisers, 1987; Mahabari et al., 1996).

The NU and RE significantly increased with increasing time of USG application from 0 to 14 DAT, above which these parameters decreased. This has led to the conclusion that 14 DAT is the optimum time of USG application for optimal N uptake and recovery efficiency. Therefore, the application of USG at 14 DAT can be recommended among other treatments to reduce environmental pollution associated with urea fertilizer use in paddy fields. The high NU and RE observed with the 14 DAT treatment contributed to high AE as a consequence of the higher rice growth and grain yield obtained. However, the PE which is the total biomass harvested per unit of N uptake was higher for 7 DAT than 14 DAT treatment because of the low NU associated with high grain and straw yields obtained with the 7 DAT treatment.

Conclusion

The study aimed at evaluating the effect of the seedling age and different time of urea supergranule deep placement on rice growth, yield and nitrogen use efficiency. The results indicated that rice growth, yield and nitrogen use efficiency decreased with increasing age of seedlings and time of USG application. Application of USG at 7 to 14 DAT on rice transplanted at 10 to14-days resulted in the highest performances. When aged seedlings of 21 and 28-day old must be transplanted then USG should be applied at 7 to 14 DAT rather than 0 or 21 DAT to increase rice yields.

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References

Abedin, S.M.S., Mannan, M.A., Mamun, M.A.M., Rahman, G.K.M. and Mridha. J.A. (2015). Growth and Yield Performance of Tidal Local Aman Rice as Influenced by USG Application at non Tidal Condition. *Bangladesh Agronomy Journal*, **18(1)**; 71–80

Alam, M. Z., Ahmed, M., Alam, M.S., Haque, M.E. and Hossin, M.S. (2002). Performance of seedling ages and seedling raising techniques on yield and yield components of transplant Aman rice. *Pakistan Journal of Biological Sciences,* **5(11)**: 1214-1216

Ali, M.Y, Rahman, M.M. and Haq, M.F. (1995). Effect of time of transplanting and age of seedling on the performance of late planted aman rice. *Bangladesh Journal Science Ind Research* **30(1)**: 45-58.

Appel, T. (1994). Relevance of soil N mineralization, total N demand of crops and efficiency of applied N for fertilizer recommendations for cereals-Theory and application. *Journal of Plant Nutrition and Soil Science*, **157(6)**: 407-414.

Ashraf, M., Khalid, A. and Ali, K. (1999). Effect of seedling age and density on growth and yield of rice in saline soil. *Pakistan Journal of Biology Science* **2**:860-862.

Bremner, J.M. (1995). Recent research on problems in the use of urea as a nitrogen fertilizer. *Fertilizer Research*. **42**:321-329.

Craswell, E., De. Datta, S., Obcemea, W. and Hartantyo, M. (1981). Time and mode of nitrogen fertilizer application to tropical wetland rice. *Fertilizer Research*, **2**: 247–259.

Dass, A. and Chandra, S. (2013). Irrigation, spacing and cultivar effects on net photosynthetic rate, dry matter partitioning and productivity of rice under system of rice intensification in Mollisols of northern India. *Experimental Agriculture* **49(4)**:504-523.

Dobermann, A. R. (2005). *Nitrogen Use Efficiency – State of the Art.* University of Nebraska, 17.

Dobermann, A. and Fairhurst, T.H. (2000). Nutrient disorders and nutrient management. Potash and Phosphate Institute of Canada and International Rice Research Institute, Singapore.

Fan, M.X. and MacKenzie, A.F. (1995). The toxicity of banded urea to corn growth and yield as influenced by triple superphosphate. Canadian *Journal of Soil Science*, **75(1)**: 117-122.

Gaudin, R. (1988). L'ammoniac NH3, une clé pour comprendre l'efficacité des supergranules d'urée en riziculture irriguée. *L'Agronomie Tropicale* **43(1)**:30–36.

Haden, V.R., Xiang, J., Peng, S.B., Bouman, B.A.M., Visperas, R.M., Ketterings, Q.M., Hobbs, P. and Duxburyn, M.J. (2011). Relative effects of ammonia and nitrite on the germination and early growth of aerobic rice. *Journal of Plant Nutrition and Soil Science*. **174**: 292–300

Hanada, K. (1979). Differentiation and development of tiller buds in rice plants. *Japan Agricultural Research Quarterly.* **16**:79-86.

Himeda, M. (1994). Cultivation Technique of Rice Nursing Seedlings: Review of Research Papers and its Future Implementation. *Agriculture and Horticulture,* **69**: 679-683.

IRRI. (1973). *Annual report for 1972*. Los Banos, Philippines, 246 p

Keisers, J. T. (1987). Effect of timing of nitrogen top-dressing on yield and yield components of direct seeded wetland rice. *Suriname-Landbrow*, **35(1-3)**: 3-13.

Kewat, M.L., Agrawal, S.B., Agrawal, K.K. and Sharma, R.S. (2002). Effect of divergent plant spacings and age of seedlings on yield and economics of hybrid rice (Oryza sativa). *Indian Journal of Agronomy* **47**:367-371.

Kirttania, B., Sarkar, M.A.R and Paul, S.K. (2013). Performance of transplant Aman rice as influenced by tiller seedlings and nitrogen management, *Journal of Bangladesh Agricultural. University*, **11(2)**: 249–256

Kundu, D. K. and Ladha, J.K. (1995). Enhancing Soil Nitrogen Use and Biological Nitrogen Fixation in Wetland Rice. *Experimentall Agriculture*, **31**: 261–277.

Mahabari, M. B., Patil, D.S. and Kalke, S.D. (1996). Yield and uptake of nutrients as influenced by the method and time of application of nitrogen fertilizers under flood prone rice (Oryza sativa L.). *Journal of Soils and Crops*, **6**: 27-30.

Makarim, A.K., Balasubramanian, V., Zaini, Z., Syamsiah, I., Diratmadja, I.G.P.A. and Handoko, A. (2002). *Systems of rice intensification (SRI): evaluation of seedling age and selected components in Indonesia. p. 129-139. In: Bouman, B.A.M., A. Hengsdijk, B. Hardy, P.S. Bindraban, T.P. Tuong, and J.K. Ladha (eds.). International Workshop on Water-Wise Rice Production, Los Baños, Phillipines. 8-11 April 2002*. International Rice Research Institute IRRI, Los Baños, Phillipines.

Manickam, T.S. and Ramaswami, P.P. (1985). Influence of N level and source on rice yield. *International Rice Research Institute. Newsletter.* 10(5): 28.

Mishra, A., and Salokhe, V.M. (2008). Seedling characteristics and the early growth of transplanted rice under different water regimes. *Experimental Agriculture*, **44(3)**: 365–383.

Mobasser, H.R., Tar, D.B., Vojdani, M., Abadi, R.S. and Eftekhari, A. (2007). Effect of seedling age and planting space on yield and yield components of rice (Neda variety). *Asian Journal of Plant Sciences* **6(2)**: 438–40.

Mohanty, S.K., Singh, U., Balasubramanian, V., and Jha, K.P. (1999). Nitrogen placement technologies for productivity, profitability, and environmental quality of rainfed lowland rice system. In Resource Management in Rice Systems: Nutrients (pp. 57-77). *Springer Netherlands*.

Moletti, M., Giudici, M.L., Villa, B. and Fiore, G. (1992). Quale tecnica colturale per i risi Patna: Performance di sei varietà coltivate con semina in acqua e interrata a dosi diverse di azoto. *L'lnformatore Agrario*, **11**:83-95.

Nyampinga, I., Mochoge, B., Issac, O. and Gasore, E.R. (2011). *The effect of method , rate and time of urea application on nitrogen use efficiency and yield of wetland rice in Rwamagana district of Rwanda.* 4th International E-Conference on Agricultural Biosciences, 67–68.

Patra, P.S. and Haque, S. (2011). Effect of Seedling Age on Tillering Pattern and Yield of Rice (Oryza sativa L.) under System of Rice Intensification. *ARPN Journal of Agricultural and Biological Science,* **6**:33-35.

Prabha, A.C., Thiyagrajan, T.M. and Senthivelu, M. (2011). System of Rice Intensification Principles on Growth Parameters, Yield Attributes and Yield of Rice (Oryza sativa L.). *Journal of Agronomy,* **10**:27-33.

Rahimpour, L., Daliri, M.S. and Mousavi, A.A. (2013). Effect of Seedling Age on Yield and Yield Components of Rice Cultivars (Oryza sativa L.). *Annals of Biological Research*, **4**:72-76.

Rahman, K.S., Paul, S.K., Sarkar, M.A.R, and Islam, M.S. (2013). Growth Parameters of Transplant Aman Rice (cv . BRRI dhan 52) as Influenced by Age of Tiller Seedlings , Number of Tiller Seedlings Hill -1 and Level of USG. *Journal of Environmental Science and Natural Resources*, **6(2)**:101–108.

Rahman, S., and Barmon, B.K. (2015). Productivity and efficiency impacts of urea deep placement technology in modern rice production: An empirical analysis from Bangladesh. *The Journal of Developing Areas,* **49(3)**:119–134.

Rasool, R.P. Singh, S. Akhter, S. and Ramzan, S. (2016). Seedling age and nitrogen application effect on dry matter accumulation, partitioning and nutrient status of rice under temperate conditions. *Journal of Applied and Natural Science,* **8(2)**:743–746.

Ros, C., Bell, R.W. and White, P.F. (2003). Seedling vigour and the early growth of transplanted rice (Oryza sativa). *Plant and Soil*, **252**:325–337.

Salem, A.K. M., Elkhoby, W.M., Abou-Khalifa, A.B. and Ceesay, M. (2011). Effect of nitrogen fertilizer and seedling age on inbred and hybrid Rice Varieties. *American-Eurasian Journal of Agricultural and Environmental Science,* **11(5)**:640–646.

Sarkar, M.A.R., Paul, S.K. and Hossain, M.A. (2011). Effect of Row Arrangement, Age of Tiller Seedling and Number of Tiller Seedlings per Hill on Performance of Transplant Aman Rice. *Journal of Agricultural Science*, **6:**61-63.

Sarwar, N., Maqsood, M., Aftab Wajid, S. and Anwar-ul-Haq, M. (2011). Impact of Nursery Seeding Density, Nitrogen, and Seedling Age on Yield and Yield Attributes of Fine Rice. *Chilean Journal of Agricultural Research*, **71(3)**:343–349.

Sasaki, R. (2004). Characteristics and Seedlings Establishment of Rice Nursling Seedlings. *Japan Agricultural Research Quarterly*, **38**:7-13.

Savant, N.K., and Stangel, P.J. (1990).

Deep placement of urea supergranules in transplanted rice : principles and practices. *Fertilizer Research*, **25(1)**:1–83.

Shen, J. H., Shao, W. and Zang, W. (2006). Effects of sowing density, fertilizer amount in seedbed and seedling age on seedling quality and grain yield in paddy field for mechanical transplanting rice. *Acta Agronomy Sin*. **32(3)**, 402–409 (2006).

Thanunathan, K., and Sivasubramanian, V. (2002). Age of seedling and crop management practices for high density (HD) grain in rice. *Crop Research* **24**:421-424.

Uphoff,N.(2002).Systemofriceintensification (SRI) for enhancing the productivity of land, labour and water. *Journal of Agricultural Resource Management* **1(1)**:43-9.

Vishwakarma, A., Singh, J.K., Sen, A., Bohra, J.S. and Singh, S. (2016). Effect of transplanting date and age of seedlings on growth, yield and quality of hybrids under system of rice (Oryza sativa) intensification andw their effect on soil fertility. Indian *Journal of Agricultural Sciences*, **86(5)**:679–685.

Zhao, L,L., Wu, M. and Li, Y. (2011). Nutrient uptake and water use efficiency as affected by modified rice cultivation methods with irrigation. *Paddy Water Environment,* **9**:25-32