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Article

Influence of organic and inorganic nitrogen on the growth and yield of irrigated rice

Uttam Kumer Sarker, Md. Romij Uddin*, Md. Abdur Rahman Sarkar, Md. Abdus Salam and Ahmed Khairul Hasan

Department of Agronomy, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

*Corresponding author: Professor Dr. Md. Romij Uddin, Department of Agronomy, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh. Phone: +8801780370135; E-mail: romijagron@bau.edu.bd

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Abstract: The objective of this research was to evaluate the impact of organic and inorganic sources of nitrogen (N) on growth dynamics, yield, N content, N uptake and agronomic efficiency (AE) of irrigated rice. Four high-yielding *boro* (dry season irrigated) rice cultivars *viz*. BRRI dhan29, BRRI dhan59 Binadhan-8 and Binadhan-10 along with six N management combinations viz. Control (no N application), 140 kg N ha^{-1} from Prilled Urea (PU), 83 kg N ha^{-1} from Urea Super Granule (USG), 105 kg N ha^{-1} from PU + 3 t ha^{-1} Poultry manure, 112 kg N ha^{-1} from PU + 5 t ha^{-1} Cowdung and 77 kg N ha^{-1} from PU + 4 t ha^{-1} vermi compost were used in the study. The cultivar Binadhan-8 had a higher yield than all other cultivars because of the highest total dry matter (TDM), number of effective tillers $hill^{-1}$, and number of grains $panicle^{-1}$.Growth, TDM, yield, and AE were highest with 105 kg N ha^{-1} from PU + 3 t ha^{-1} Poultry manure application .The highest N uptake in grain and straw (120.1 kg ha^{-1} and 96.14 kg ha^{-1}, respectively) was shown by rice cultivar Binadhan-8. In addition, significant relationships between N concentration and growth dynamics, TDM, N content, N uptake, and yield were observed. These results indicated that cultivars with the capacity to uptake more N can produce more yield and N application along with poultry manure could enhance growth, yield, AE. Therefore, the combined application of N sources in the form of PU + Poultry manure can produce good performances in terms of growth and yield of HYV rice under irrigated condition.

Keywords: high yielding rice cultivars; organic manure; total dry matter; agronomic efficiency

1. Introduction

Rice (*Oryza sativa* L.) is considered as most important staple foods for nearly half of the world's population, most of them living in developing countries. It supplies 50-60% of the total calories to 2.7 billion people (Metwally *et al.*, 2011). About 11% of world's agricultural land is occupied by rice and ranks second in terms of cultivated area (Tumrani *et al.*, 2015). The slogan 'Rice is Life' is appropriate for Bangladesh, as this crop plays a vital role in the national food security and is a means of livelihood for millions of rural households in the country. The population of Bangladesh is approximately 160 million and continues to grow by two million persons every year; at this rate, there will an increase of 30 million people over the next 20 years (BPF, 2015). At the current rate of population growth, superior resource management technologies for rice yield will be required to meet the growing demand.

Rice soil system supports fertility protection and build-up of organic matter in soils, and is the backbone of long-term sustainability of the wetland rice systems (Sahrawat, 2004). Nitrogen (N) condition of soils is sustained by maintaining balance between N loss of crop harvest and N gain from biological N fixation in primary rice farming of the pre-chemical period (Ladha and Peoples, 1995). However, in present exhaustive rice mono-cropping systems, this balance has been troubled with inputs of mineral fertilizers (Ladha *et al.*, 2000). Gradual turn down of organic matter content and change of native N status in the soils due to continuous use of chemical fertilizers without organic sources, which results in lower productivity in the rice cultivation system (Fu *et al.,* 2014; Pei *et al.,* 2015). Moreover, the application of chemical fertilizers is expensive and progressively lead to the environmental problems. Although rice is a serious N consumer, the N fertilizer utilization efficiency in rice is extremely low under tropical conditions and usually ranges from 15% to 35% (de Dutta, 1986). N use efficiency is vital for the economic sustainability of cropping systems (Fageria and Baligar, 2005; Amanullah *et al.,* 2010). Sufficient N sources and rates are very important, which increase yield, reduce the cost of production and environmental pollution (Fageria *et al.,* 2011).

One of the most important reasons for low rice yield in Bangladesh is imbalanced nutrient application. Combined use of chemical fertilizers and organic manure has been widely recommended for sustaining agricultural production (Amanullah and Inamullah, 2015; Amanullah and Khan, 2015; Amanullah and Khalid, 2016). Superior management practices such as incorporation of crop residue, animal manures with chemical fertilizers application enhance soil organic carbon and improve crop productivity (Six *et al.,* 2002; Vanden *et al.,* 2003; Rakshit *et al.,* 2008; Amanullah and Hidayatullah, 2016). Application of organic manures and chemical fertilizers is responsible for 50–60% of the increase in field crop productivity (Dipa, 2006). Researches from diverse parts of the world have suggested that application of animal manures boost up the yield of various crops (Olayinka, 1996; Olayinka *et al.,* 1998; Ayoola and Makinde, 2008; Hidayatullah *et al.,* 2013; Iqbal *et al.,* 2015; Amanullah and Khalid, 2016). Moreover, nutrients from organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Ge *et al.,* 2010; Hidayatullah *et al.,* 2013; Amanullah and Khalid, 2016).

There is information related to N management along with organic manures for rice cultivars in general, but there is little information on N management with Prilled Urea (PU), Urea Super Granule (USG) and organic manures for irrigated and high-yield rice (*boro* rice). Such information is vital for identifying the physiological and morphological traits to support the selection and breeding of high-yield rice cultivars. Considering these factors, this study is conducted to investigate the impacts of different organic sources (animal manures) in various combinations with inorganic nitrogen (PU and USG) on plant growth, yield and agronomic efficiency of high yielding rice cultivars under Old Brahmaputra Floodplain of Bangladesh.

2. Materials and Methods

2.1. Site description

The field experiment was conducted at experimental farm of the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh (latitude: 24°42´55´´, longitude: 90°25´47´´) during *boro* (dry) seasons of 2015-16 (November to May). The experimental site (Mymensingh) is under a humid subtropical monsoon type of climate. The climate is humid subtropical monsoon. The physicochemical properties of the soil before the beginning of the experiment are shown in Table 1.

2.2. Experimental design and treatments

The treatments consist of four high yielding rice cultivars viz. BRRI dhan29, BRRI dhan59, Binadhan-8 and Binadhan-10 and six N management along with organic manures namely, Control (no N application), 140 kg N ha^{-1} from Prilled Urea (PU), 83 kg N ha^{-1} from Urea Super Granule (USG), 105 kg N ha^{-1} from PU + 3 t ha^{-1} Poultry manure (POM), 112 kg N ha^{-1} from PU + 5 t ha^{-1} Cowdung (CD), 77 kg N ha^{-1} from PU + 4 t ha^{-1} Vermi Compost (VC). The selected cultivars were the most popular and high-yielding ones cultivated during the *boro* season. The experiment was conducted following Randomized Complete Block Design (RCBD) and replicated thrice. The unit plot size was 4m×2.5 m and total number of plot was 72. The distance between individual plots was 0.5 m and in between replication was 1 m.

2.3. Field preparation and fertilizer application

The field was prepared by 4-5 ploughing followed by laddering. Fertilizer was applied as per specification in case of N treatment. Other fertilizers were @ 20-65-18-1.3 in the form of P-K-S-Zn. The fertilizer sources were Urea, TSP, MOP, Gypsum and Zinc sulphate. Calculation of nutrients on IPNS basis was done and only required amount were applied from fertilizers. Whole amounts of other fertilizers except Urea were applied during the final land preparation. USG was applied among every four hills in alternate row after one week of transplanting. Urea was applied in three equal splits at 15, 40 and 70 days after transplanting (DAT), respectively.

2.4. Crop management

Forty days old seedlings (previously grown in seed bed) of the cultivars were collected from Agronomy Field Laboratory. Seedlings were uprooted carefully from the bed and bundled with proper care and brought for transplanting in the pots. The seedlings were transplanted in the plot at 21th January, 2016. During the growth period, especially in the early stages, sometimes weeds were observed and uprooted by hand. Other operations were done as and when necessary. Soil moisture was maintained at about field capacity during the experimentation.

2.5. Plant and growth dynamics measurement

Observations on growth dynamics were made at active tillering (AT), panicle initiation (PI), flowering (FL), and physiological maturity (PM). The parameters to assess growth dynamics, such as plant height, leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), and net assimilation rate (NAR) were recorded for each pot through destructive sampling. For each destructive sample, a plant was uprooted and washed with water. The leaf blades were separated from the leaf sheath and leaf area was measured by a leaf area meter (LI 3100, Licor, Inc., Lincoln NE, USA). Leaf area index was accordingly calculated from leaf area data. After measurement of leaf area, the plant samples were dried in an electric oven at 65°C for 72 hour until they reached at constant weight, and their dry weights were recorded. LAI, CGR, RGR, and NAR were calculated following the standard formulae (Radford 1967; Hunt 1978).

2.6. Measurement of total dry matter (TDM)

Firstly, biomass partitioning in the form of sheath weight, leaf weight, root weight, and total dry matter was calculated for each N management level for all cultivars. Then, the sheath, leaf, and root dry weight was calculated during AT, PI, FL, and PM by placing the plant samples in the oven at 65°C for 72 h. Finally, total dry matter of the plant was determined by adding shoot dry matter, including leaf blade, leaf sheath, Culm, and panicle (when applicable) and root dry matter.

2.7. Estimation of agronomic efficiency and apparent recovery efficiency

2.7.1. Agronomic efficiency (AE)

The agronomic efficiency of N (AE_N) is the incremental efficiency of applied N. AE_N reflects how much additional yield is produced for each kg of N applied. The AE from applied N is the ratio of kg grain yield increase per kg N applied (Dobermann and Fairhurst, 2000).

$$AE_N = \frac{GY_{+N} - GY_{0N}}{FN}$$

Where, AE_N is the agronomic efficiency of N, GY_{+N} is the grain yield in a treatment with N application, GY_{0N} is the grain yield in a treatment without N application and FN is the amount of fertilizer applied in kg ha^{-1}.

2.7.2. Recovery efficiency (RE)

Recovery efficiency is the uptake efficiency for the applied nutrient. RE is the answer to the question of how much N applied was recovered and taken up by the crop. RE from applied N is the ratio of kg N taken up per kg N applied (Dobermann and Fairhurst, 2000).

$$RE_N = \frac{UN_{+N} - UN_{0N}}{FN} \times 100$$

Where, RE_N is the recovery efficiency of N, UN_{+N} is the total plant N uptake measured in the aboveground biomass at physiological maturity (Kg ha^{-1}) and UN_{0N} is the total N uptake without addition of N (Kg ha^{-1}).

2.8. Measurement of yield and yield components

Maturity date was identified when 90% of grains had matured. At maturity, the whole plant was cut at the ground level with a sickle. The harvested crop from each pot was bundled separately and tagged appropriately. After recording data for plant height and panicle length for each plant, plant materials were sun dried for grain collection. Finally, grain and straw yield and yield contributing parameters were recorded separately.

2.9. Data analysis

Data on crop growth, yield components, and yield of rice were compiled and tabulated for statistical analysis. The recorded data on various plant characters were statistically analyzed to find out the significance of variation resulting from the experimental treatments. All the collected data were analyzed following analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984) using a computer operated program namely MSTAT-C.

3. Results

3.1. Growth dynamics

Significant effects of different cultivars and N sources on plant height except AT, PI and LAI except AT are presented in Table 2. Plant height increased progressively over time attaining the greatest height at PM. The highest plant height (93.17 cm) at FL was measured for Binadhan-10 along with 105 kg N from PU+3 t ha^{-1} POM and the lowest (75.43 cm) for BRRI dhan59 with no N application (control). LAI is the essential physiological parameter, which indicated the size the crop assimilated per unit area. In respect of growth stage, LAI increased stridently, reaching a peak at FL and then decreased irrespective of treatment differences. Greatest LAI (5.13) was obtained at FL by Binadhan-8. LAI reduced after FL due the loss of some leaves through senescence. A significant relationship (R^2=0.97, $p<0.01$) between grain yield and LAI at FL is shown in Figure 1a. Cultivars having a higher LAI have the possibility to absorb more solar radiation, photosynthesize more, and ultimately produce higher yields. It was observed that CGR increased parallel with the increase in leaf area over the time until FL and then decreased (Table 3).CGR at 83 kg N ha^{-1} from USG remained highest (22.09 g cm^{-2} day^{-1}) at FL for Binadhan-8 which is statistically similar to 105 kg N from PU+3 t ha^{-1} POM for the same cultivar and a minimum was noted at control for BRRI dhan59. Grain yield variations for cultivars were significantly and positively correlated (R^2=0.93, $p<0.01$) with CGR at FL (Figure 1b). Irrespective of treatments, RGR was higher at the early stage (AT) and showed a diminishing trend with the progress of plant age (Table 3). The decrease in RGR was probably due to increased metabolically active tissue, which contributed less to plant growth. It was observed that BRRI dhan59 cultivar had the highest RGR at both FL and PM. The trend in NAR based on treatments was downward (Table 3). The highest NAR was obtained from Binadhan-8 along with 105 kg N from PU+3 t ha^{-1} POM at PM which are statistically identical to 83 kg N ha^{-1} from USG and 112 kg N from PU+5t ha^{-1} CD.

3.2. Total dry matter, grain yield and yield components

TDM differed significantly for cultivars and N sources at FL (Table 4). TDM was highest in Binadhan-8 with 105 kg N from PU + 3 t ha^{-1} POM which was statistically similar to 83 kg N ha^{-1} from USG. The rice cultivar having greatest value for total dry matter has the possibility of producing highest yield. Grain yield variations for cultivars were significantly positively correlated (R^2=0.94, $p<0.01$) with TDM (Figure1c). The ANOVA for grain yield and yield components, and their mean comparisons is shown in Table 4. Response of cultivars and N sources on grain yield was significant. The highest grain yield (6.35 t ha^{-1}) was recorded from Binadhan-8 when 105 kg N from PU + 3 t ha^{-1} POM was applied which was statistically similar to 83 kg N ha^{-1} from USG. The lowest grain yield (2.96 t ha^{-1}) was obtained from BRRI dhan59 with no N application (control) treatment. Among the cultivars, because Binadhan-8 had higher physiological indices, it had the highest yield. There were significant interactions between cultivars and N sources on yield component. Effective tillers $hill^{-1}$ with 105 kg N from PU + 3 t ha^{-1} POM and 83 kg N ha^{-1} from USG for Binadhan-8 were 20.93% and 18.71% respectively, than with no N application. Grain yield variations for cultivars were significantly positively correlated (R^2=0.81, $p<0.01$) with effective tillers $hill^{-1}$ (Figure 2a). Similiar trend of result was observed for grains $panicle^{-1}$ and there was a significant positive correlation (R^2=0.92, $p<0.01$) between grains $panicle^{-1}$ and grain yield (Figure 2b). There was no significant effect of cultivars and N sources panicle length and 1000 grain weight.

3.3. N content (%) and uptake (kg ha^{-1})

N content (%) in both grain and straw was not significant for cultivars and N sources where as N uptake in grain and straw were significantly influenced by N sources and cultivar treatments (Table 5). The grain N content (%) varied from 1.13% to 1.88% and numerically Binadhan-8 had the highest N content (%) among cultivars. In the straw, N content (%) varied from 0.35% to 1.28%. N uptake in grain was highest (120.1 kg ha^{-1}) for105 kg N from PU + 3 t ha^{-1} POM followed by 83 kg N ha^{-1} from USG for Binadhan-8. Similar trend of result was observed for N uptake in straw and N uptake in straw was also lower than that of grain irrespective of treatment differences. N content in grain had a highly significant positive association with grain yield (R^2= 0.77, $p<0.01$) as is shown in Figure 3a. Hence, increasing N concentration in grain can increase rice grain yield. A similar trend was also observed for N content in straw and grain yield (Figure 3b).Uptake of N in the grain and straw followed dry matter yield of these two plant parameters. Uptake of N in grain (R^2= 0.92, p<0.01) as well as in straw (R^2 = 0.93, p<0.01) had a highly significant association with grain yield (Figures 3c and 3d).

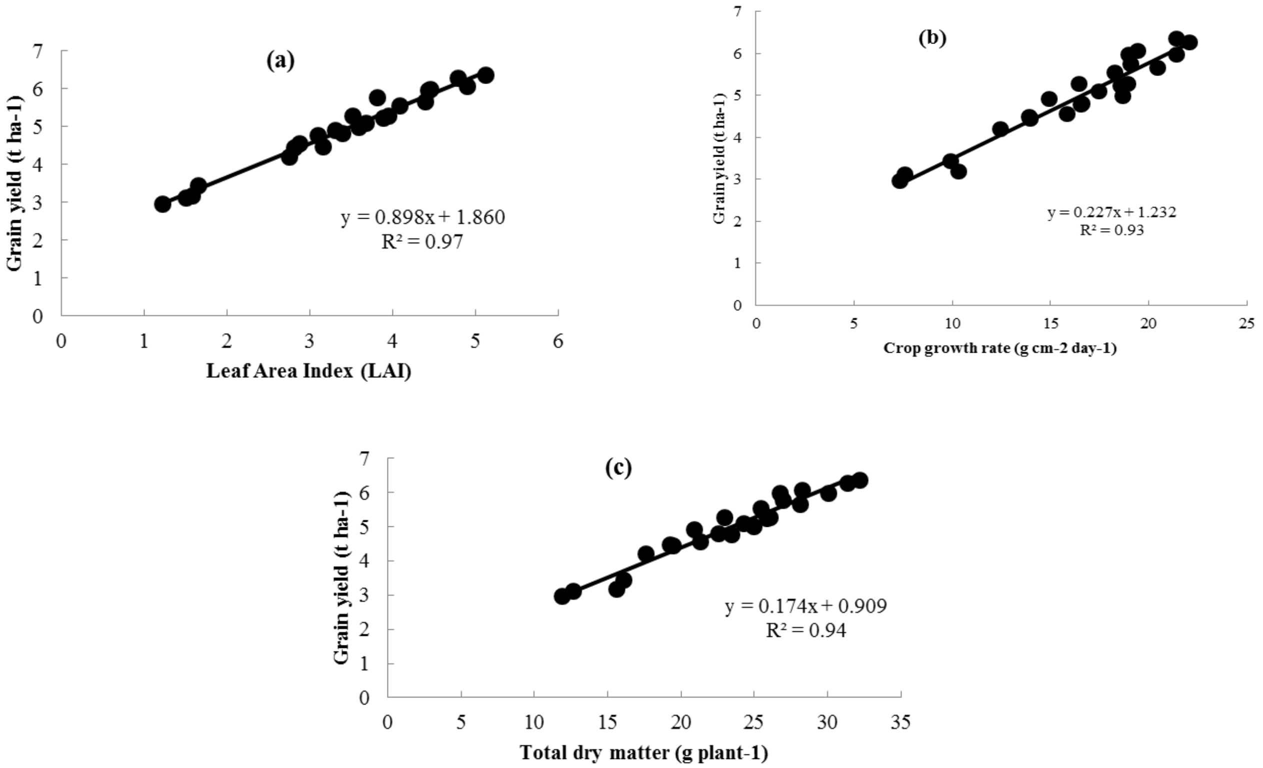

Figure 1. Relationship between grain yield and leaf area index (a), crop growth rate (b), and total dry matter (c) at flowering.

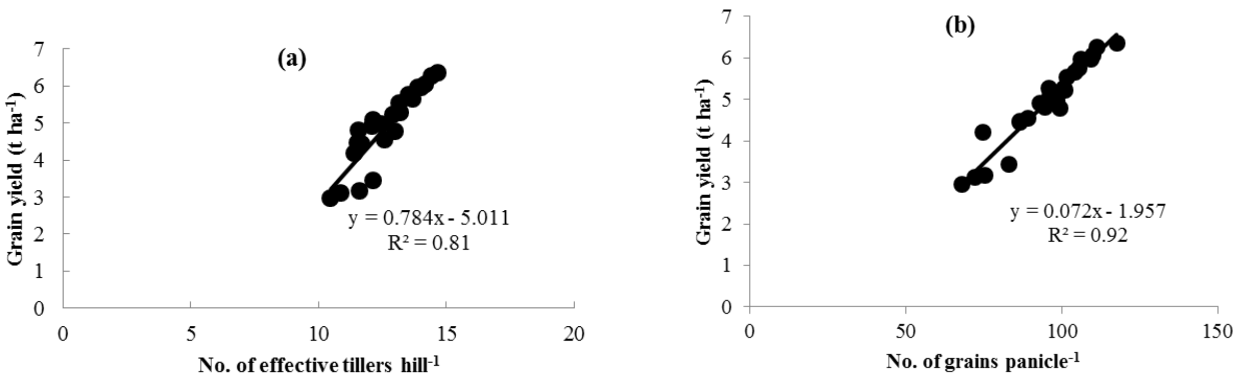

Figure 2. Relationship between grain yield and effective tillers hill^{-1} (a), and grains panicle^{-1} (b).

3.4. Agronomic efficiency (AE) and recovery efficiency (RE) of N

AE is the basis for economic and environmental efficiency, and more sustainable agricultural practices are required in farm management for improving crop yield performance and to reduce the environmental risks of farming. Agronomic efficiency (AE) is used to explain the ability of yield increase per kilogram pure N and it was significant for N application among the cultivars and sources. The highest AE was observed in Binadhan-8 along with 105 kg N from PU + 3 t ha^{-1} POM followed by 83 kg N ha^{-1} from USG for the same cultivar. RE was the main index used to describe the characteristics of N uptake and utilization in rice. The RE varied from 23.11 to 110.3% with an average value of 58.54%. The highest yield producing genotype, Binadhan-8 had highest value for RE.

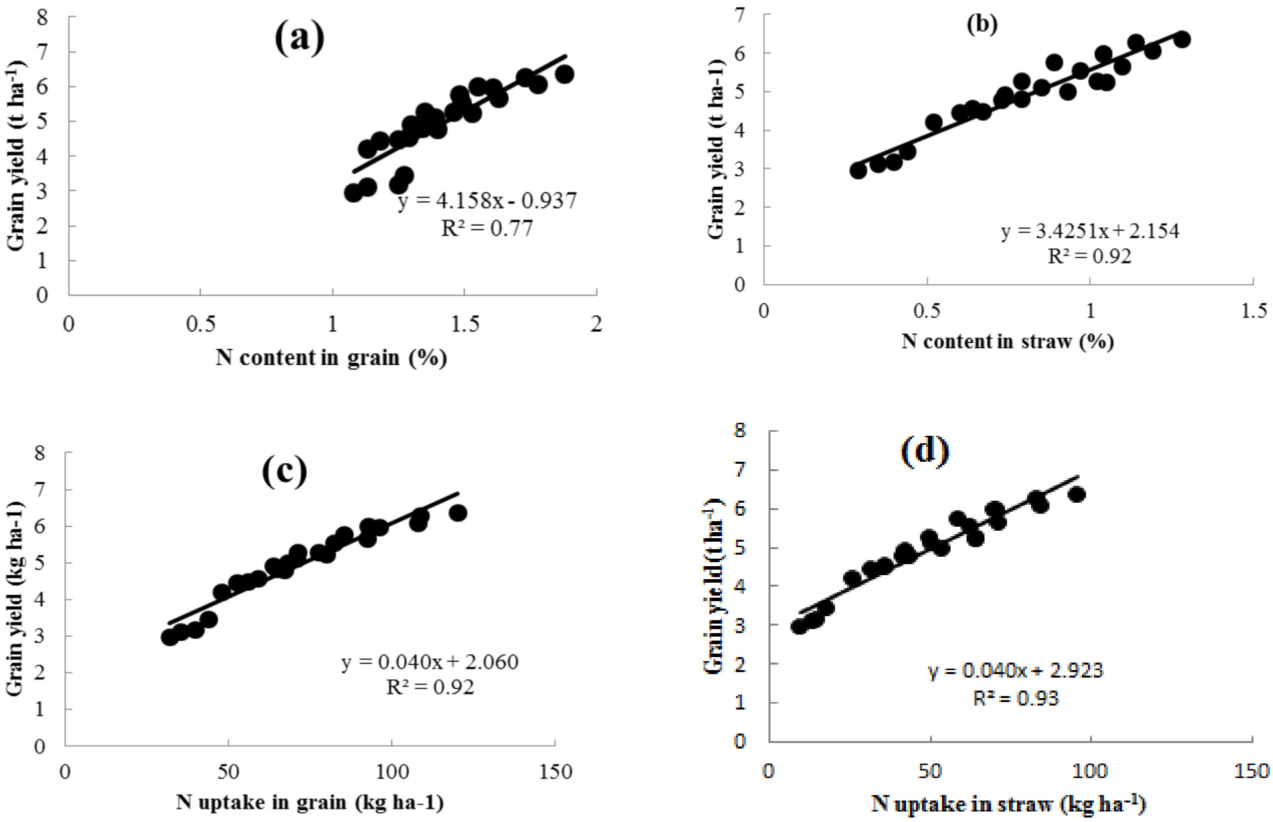

Figure 3. Relationship between grain yield and N content in grain (a), N content in straw (b), N uptake in grain (c), and N uptake in straw (d).

Table 1. Physicochemical properties of soil before start of the experiments.

Soil property	Values
Soil texture	Clay loam
pH–H_2O	6.13
Ec (µs/cm)	648
Organic carbon (%)	1.274
Total N (%)	0.112
Available P (ppm)	28.2
Available K (ppm)	83.64
Available S (ppm)	25.90

Table 2. Plant height and leaf area index of *boro* rice cultivars at different sources of nitrogen.

Cultivars (V)	N management (N)	Plant height (cm)				Leaf area Index (LAI)			
		AT	PI	FL	PM	AT	PI	FL	PM
BRRI dhan29	Control	30.37	53.02	79.50 k	79.97 jk	0.03	0.79 lm	1.51l	1.36 ij
	140 kg N ha^{-1} from PU	31.36	56.11	82.46 j	83.37 ghi	0.07	0.81 j-m	2.82 k	2.71 gh
	83 kg N ha^{-1} from USG	32.78	61.67	86.28gh	86.97 ef	0.08	0.97 fg	3.95 de	3.59 c
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	34.22	62.94	89.41de	87.64de	0.08	1.03ef	4.40c	4.05b
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	31.67	60.63	83.31 ij	84.79 e-h	0.07	0.87 h-k	3.31ij	3.23 def
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	31.92	61.33	84.97 hi	85.90 e-h	0.08	0.93 gh	3.68 fg	3.47 cd
BRRI dhan59	Control	27.60	48.11	75.43 m	76.03 l	0.04	0.77 m	1.22 m	1.12 j
	140 kg N ha^{-1} from PU	28.56	51.00	77.33 l	77.92 kl	0.05	0.79 klm	2.76 k	2.61h
	83 kg N ha^{-1} from USG	30.46	56.55	80.03 k	83.61 f-i	0.07	0.91 ghi	3.60 gh	3.36 cde
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	31.07	57.00	83.09 j	84.50 e-h	0.07	0.98 fg	3.89 def	3.57 c
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	29.33	54.47	77.67 l	79.88jk	0.06	0.83 i-m	3.16 j	2.94 fg
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	30.33	55.78	79.00 kl	80.91 ijk	0.07	0.86 h-l	3.40 hi	3.14ef
Binadhan -8	Control	31.32	55.56	82.63 j	82.65 hij	0.06	0.88 hij	1.65 l	1.53 i
	140 kg N ha^{-1} from PU	31.67	58.45	85.36 gh	85.91 e-h	0.08	1.02 ef	3.10 j	3.01 fg
	83 kg N ha^{-1} from USG	33.44	64.46	88.17 ef	93.28 bc	0.10	1.25 ab	4.79 b	4.06 b
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	35.92	65.67	90.76 cd	96.97 a	0.10	1.31 a	5.13 a	4.67 a
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	31.85	61.56	86.05 gh	86.24 efg	0.09	1.08 e	3.82 ef	3.66 c
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	32.61	62.45	87.00 fg	90.88 c	0.10	1.18 bc	4.43 c	4.08 b
Binadhan -10	Control	32.78	60.56	85.00 hi	85.95 e-h	0.05	0.81 j-m	1.58 l	1.46 i
	140 kg N ha^{-1} from PU	33.45	63.55	89.67 de	90.48 cd	0.07	0.97 fg	2.88 k	2.73 gh
	83 kg N ha^{-1} from USG	35.26	66.11	92.67 ab	96.49 a	0.09	1.16 cd	4.46 c	4.14 b
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	36.44	67.10	93.17 a	97.41 a	0.10	1.22 bc	4.90 b	4.48 a
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	33.69	64.55	91.06 bcd	93.38 bc	0.08	1.03 ef	3.52 ghi	3.44 cde
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	34.76	65.22	91.85 abc	94.46 ab	0.09	1.09 de	4.09 d	3.94 b
ANOVA									
Cultivars (V)		**	**	**	**	**	**	**	**
N management (N)		**	**	**	**	**	**	**	**
V × N		NS	NS	*	*	NS	**	**	**
CV (%)		3.19	3.85	1.16	2.04	11.84	4.41	3.64	5.46

Within a column, means followed by same letters are not significantly different at 5 % probability level by Duncan's Multiple Range Test (DMRT)

AT active tillering, *PI* panicle imitation, *Fl* flowering, *PM* physiological maturity, *PU* Prilled Urea, *USG* Urea Super Granule, *POM* Poultry Manure, *CD* Cowdung, *VC* Vermi Compost

* Significant difference at $P \leq 0.05$, ** Significant difference at $P \leq 0.01$, NS- Non-significant

Table 3. Effect of different sources of nitrogen on CGR, RGR and NAR of rice cultivars at different growth stages.

Cultivars	N management	CGR (g cm^{-2}day^{-1})			RGR (g^{-1}g^{-1}day)			NAR (mg cm^{-2}day^{-1})		
		AT-PI	PI-FL	FL-PM	AT-PI	PI-FL	FL-PM	AT-PI	PI-FL	FL-PM
BRRI dhan29	Control	5.41 kl	7.59 l	4.37 lm	41.41 a	14.47 f	4.85 ijk	0.873	0.296 e	0.130 cd
	140 kg N ha^{-1} from PU	6.16 ij	13.96 i	5.52 l	40.02 b	19.29 a-d	4.10 l	0.880	0.370 a-d	0.090 g
	83 kg N ha^{-1} from USG	7.84 ef	18.95 cde	10.70 f-i	37.12 gh	19.74 a-d	5.75 e-h	0.943	0.390 abc	0.120 de
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	8.46 de	20.47 bc	9.89 hij	37.30 fgh	19.85 abc	4.91 ijk	0.966	0.380 a-d	0.100 fg
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	6.59 hi	14.94 hi	11.3 efg	38.68 b-g	19.23 a-d	7.16 ab	0.866	0.350 a-e	0.150 ab
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	7.48 fg	17.46 ef	9.72 hij	38.11 d-h	19.57 a-d	5.56 fgh	0.930	0.380 a-d	0.120 de
BRRI dhan59	Control	4.92 l	7.31 l	3.89 m	42.10 a	14.91 f	4.67 jkl	0.860	0.320 de	0.140 bc
	140 kg N ha^{-1} from PU	5.77 jk	12.42 j	5.47 l	41.91 a	18.83cd	4.46 kl	0.900	0.340 b-e	0.090 g
	83 kg N ha^{-1} from USG	7.13 gh	18.69 de	9.40 ij	38.98 b-e	20.94 a	5.32 hi	0.930	0.410 a	0.120 de
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	8.01 def	18.60 de	9.73 hij	38.85 b-f	19.62 a-d	5.25 hij	0.990	0.380 a-d	0.116 def
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	5.94 jk	13.90 i	11.37 efg	39.25bcd	19.72 a-d	7.58 a	0.880	0.350 a-e	0.160 a
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	6.73 hi	16.58 fg	9.99 g-j	39.69 bc	20.26 abc	6.02 def	0.930	0.390 abc	0.133 bcd
Binadhan -8	Control	6.61 hi	9.90 k	4.60lm	42.05a	14.89 f	4.19 l	0.930	0.350 a-e	0.130 cd
	140 kg N ha^{-1} from PU	7.57 fg	16.54 fg	9.03 jk	38.49 b-g	18.81cd	5.34 ghi	0.873	0.390 abc	0.130 cd
	83 kg N ha^{-1} from USG	10.0 b	22.09 a	15.8 b	37.30 fgh	18.71 cd	6.73 bc	0.940	0.360 a-d	0.160 a
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	11.4 a	21.41 ab	17.67 a	37.96 d-h	16.97e	7.16 ab	1.03	0.330 cde	0.160 a
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	8.61 d	19.08 cd	13.45 c	38.32 c-h	18.96 bcd	6.65 bc	0.920	0.380 a-d	0.160 a
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	9.43 c	21.41 ab	12.95 cd	37.42 e-h	19.10 a-d	5.91 d-g	0.930	0.380 a-d	0.130 cd
Binadhan -10	Control	5.81 jk	10.30 k	3.45 m	41.78 a	16.65 e	3.29 m	0.890	0.383 abc	0.100 g
	140 kg N ha^{-1} from PU	6.11 ij	15.85 gh	7.96 k	37.69 d-h	20.74 ab	5.21 hij	0.760	0.393 ab	0.120 de
	83 kg N ha^{-1} from USG	8.41de	19.00 cde	12.88 cd	36.72 h	18.99 bcd	6.46 cd	0.866	0.336 b-e	0.130cd
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	9.467c	19.45 cd	12.35 cde	37.17 gh	17.94 de	5.93 def	0.916	0.320 de	0.110 ef
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	7.14 gh	16.46 fg	10.92 e-h	37.85 d-h	19.28 a-d	6.40 cd	0.820	0.353 a-e	0.140 bc
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	7.87 ef	18.25 de	11.57 def	37.38 fgh	19.40 a-d	6.16 cde	0.860	0.350 a-e	0.123cde
ANOVA										
Cultivars (V)		**	**	**	**	**	**	**	NS	**
N management (N)		**	**	**	**	**	**	**	*	
V × N		**	**	**	*	**	**	NS	*	**
CV (%)		4.65	5.27	8.11	2.11	5.12	5.73	5.86	7.35	11.73

Within a column, means followed by same letters are not significantly different at 5 % probability level by Duncan's Multiple Range Test (DMRT)

AT active tillering, *PI* panicle initiation, *Fl* flowering, *PM* physiological maturity, *CGR* crop growth rate, *RGR* relative growth rate, , *NAR* net assimilation rate, *PU* Prilled Urea, *USG* Urea Super Granule, *POM* Poultry Manure, *CD* Cowdung, *VC* Vermi Compost

* Significant difference at P ≤ 0.05, ** Significant difference at P ≤ 0.01, NS- Non-significant

Table 4.Total dry matter, grain yield and yield components of *boro* rice cultivars at different sources of nitrogen.

Cultivars	N management	TDM at FL (g plant^{-1})	Grain yield (t ha^{-1})^{a}	Effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)
BRRI dhan29	Control	12.69 n	3.12 kl	10.87 l	19.67	72.20 mn	22.79
	140 kg N ha^{-1} from PU	19.50 k	4.45 ij	11.68 k	21.92	86.79 kl	23.33
	83 kg N ha^{-1} from USG	26.10 de	5.28 ef	13.17 f	23.53	100.6 efg	23.91
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	28.17 c	5.66 cd	13.67 de	24.28	104.2 de	24.21
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	20.93 jk	4.91 fgh	12.07 j	22.64	93.16 ij	24.72
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	24.26 fgh	5.10 fg	12.13 ij	23.20	96.37 ghi	25.56
BRRI dhan59	Control	11.92 n	2.96 l	10.47 m	17.79	68.11 n	22.69
	140 kg N ha^{-1} from PU	17.59 l	4.20 j	11.37 k	20.34	74.72 m	23.18
	83 kg N ha^{-1} from USG	25.00 efg	4.99 fg	12.47 hi	22.39	98.52 fgh	23.78
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	25.85 def	5.23 ef	12.88 fg	22.62	101.1 ef	23.94
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	19.26 k	4.48 ij	11.53 k	20.70	86.57 kl	24.28
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	22.58 hij	4.81 ghi	11.57 k	21.31	94.49 hi	24.57
Binadhan -8	Control	16.08 lm	3.44 k	12.13 j	20.88	83.16 l	25.48
	140 kg N ha^{-1} from PU	23.48 gh	4.78 ghi	13.00 f	22.15	99.35 fg	27.46
	83 kg N ha^{-1} from USG	31.40 ab	6.27 a	14.40 ab	24.09	111.2 b	28.13
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	32.19 a	6.35 a	14.67 a	26.41	117.6 a	28.20
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	26.95 cd	5.76 bcd	13.53 e	23.10	105.7 cd	27.82
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	30.08 b	5.97 abc	14.00 cd	23.82	109.3 bc	27.99
Binadhan -10	Control	15.65 m	3.18 kl	11.60 k	19.84	75.28 m	24.44
	140 kg N ha^{-1} from PU	21.34ij	4.55 hij	12.58 gh	22.03	89.11 jk	27.03
	83 kg N ha^{-1} from USG	26.78 cde	5.98 abc	13.87 cde	23.89	106.2 cd	27.80
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	28.30 c	6.06 ab	14.17 bc	25.16	109.9 bc	27.90
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	22.99 hi	5.28 ef	13.07 f	22.27	96.07 ghi	27.61
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	25.46 def	5.54 de	13.13 f	23.20	101.7 def	27.68
ANOVA							
Cultivars (V)		**	**	**	**	**	**
N management (N)		**	**	**	**	**	**
V × N		*	*	*	NS	*	NS
CV (%)		4.26	4.31	1.55	3.69	2.66	7.14

Within a column, means followed by same letters are not significantly different at 5 % probability level by Duncan's Multiple Range Test (DMRT)

PU Prilled Urea, *USG* Urea Super Granule, *POM* Poultry Manure, *CD* Cowdung, *VC* Vermi Compost, *TDM* Total Dry Matter, *FL* flowering

* Significant difference at $P \leq 0.05$, ** Significant difference at $P \leq 0.01$, NS- Non-significant

[a] Grain yield is at 14 % moisture content

Table 5. Content, uptake, agronomic efficiency and recovery efficiency of nitrogen at different sources of nitrogen.

Cultivars	N management	N content in grain (%)	N uptake in grain (kg ha^{-1})	N content in straw (%)	N uptake in straw (kg ha^{-1})	Agronomic efficiency (kg kg^{-1})	Recovery efficiency (%)
BRRI dhan29	Control	1.13	35.38 no	0.35	13.51 jk	-	-
	140 kg N ha^{-1} from PU	1.18	52.67 jk	0.60	31.76 h	9.551gh	25.38 l
	83 kg N ha^{-1} from USG	1.46	77.57 fg	1.02	64.59 d	15.45 cde	71.82 d
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	1.63	92.48 cd	1.10	71.65 c	18.17 b	82.31 c
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	1.30	63.98 hi	0.74	42.91 g	12.83 f	41.42 hi
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	1.39	70.88 gh	0.85	50.63 f	14.15 ef	51.87 fg
BRRI dhan59	Control	1.08	32.00 o	0.29	9.610 k	-	-
	140 kg N ha^{-1} from PU	1.13	47.89 kl	0.52	26.07 i	8.857 h	23.11 l
	83 kg N ha^{-1} from USG	1.37	68.40 h	0.93	53.83 ef	14.45 ef	43.14 hi
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	1.53	80.09 ef	1.05	64.51 d	16.17cd	73.57 d
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	1.25	56.11 j	0.67	36.54 h	10.86 g	36.46 ij
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	1.34	64.77 hi	0.79	43.72 g	13.22 f	47.77 gh
Binadhan -8	Control	1.27	43.82 lm	0.44	18.01 j	-	-
	140 kg N ha^{-1} from PU	1.40	67.26 h	0.73	42.15 g	9.62 gh	33.98 jk
	83 kg N ha^{-1} from USG	1.73	108.9 b	1.14	83.59 b	20.26 a	98.49 b
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	1.88	120.1 a	1.28	96.14 a	20.86 a	110.3 a
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	1.48	85.46 de	0.89	58.94 de	16.60 bcd	58.98ef
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	1.61	96.29 c	1.04	70.43 c	18.07 b	74.91 d
Binadhan -10	Control	1.25	39.75 mn	0.40	14.84 jk	-	-
	140 kg N ha^{-1} from PU	1.29	59.00 ij	0.64	36.19 h	9.76 gh	29.00 kl
	83 kg N ha^{-1} from USG	1.55	93.05 c	1.04	70.96 c	20.02 a	56.85 f
	105 kg N ha^{-1} from PU+ 3t ha^{-1} POM	1.78	108.1 b	1.19	85.11 b	20.57 a	98.98 b
	112 kg N ha^{-1} from PU+ 5t ha^{-1} CD	1.35	71.19 gh	0.79	50.06 f	15.02 de	47.62 gh
	77 kg N ha^{-1} from PU+ 4t ha^{-1} VC	1.49	82.51 ef	0.97	62.77 d	16.86 bc	64.78e
ANOVA							
Cultivars (V)		**	**	**	**	**	**
N management (N)		**	**	**	**	**	**
V × N		NS	**	NS	**	**	**
CV (%)		5.52	6.00	5.90	6.83	7.32	8.61

Within a column, means followed by same letters are not significantly different at 5 % probability level by Duncan's Multiple Range Test (DMRT)

** Significant difference at P ≤ 0.01, NS - Non significant

4. Discussion

Growth and yield characters of the plant represent the real-time nutritional status of soil and the results may provide the information on future crop nutrient management. The results of our study demonstrated that application of different organic manures along with PU and USG significantly improved growth parameters, yield and yield components of high yielding rice. The differences in the C:N ratios of different organic sources (Amanullah and Hidayatullah, 2016) may have influenced the availability and uptake of nutrients, especially N, by the plants that affected growth. Hidaytullah (2015) found better growth for hybrid rice (Pukhraj) with application of poultry manure due to its lower C:N ratio than other organic sources. Variation in growth parameters while using organic manure was reported earlier by Babu *et al.* (2001) and Rani *et al.* (2001). Recently, (Hidaytullah, 2015) and Amanullah and Khalid (2015), and Amanullah and Hidayatullah (2016) revealed that application of poultry manure (with lower C:N ratio) increased growth of hybrid rice because of the higher nitrogen availability. Mohandas *et al.* (2008) and Enujeke (2013) also reported that application of poultry manure increased plant growth because more nutrients were made readily available and easily absorbable by receiving plants leading to faster growth and development. According to Hassanuzazzaman *et al.* (2010), a large amount of plant nutrients are supplied by poultry manure and can contribute to improving crop growth.

The increases in yield components and grain yield after the application of 105 kg N from PU + 3 t ha^{-1} POM compared to other organic manure along with PU and sole PU. This might also be due to low C/N ratio in POM. Suzuki (1997) stated that the organic materials with high C/N ratios are likely to compete for N, which may lead to N deficiency in extreme cases. In addition, the organic sources with higher C/N ratios may probably undergo less decomposition under waterlogged condition. Previously, Sahrawat (2006) has discovered that the soil organic matter accumulated in submerged soils had inefficient decomposition. These results agree with the results of Ebaid and El-Refaee (2007), El-Refaee *et al.* (2006) and Hossaen *et al.* (2011). They also reported that the increase in rice yield is associated with the increase in yield attributes. In relation to grain yield components, our study showed that grain yield was closely related to the number of effective tillers $hill^{-1}$ and grains $panicle^{-1}$. These types of responses are in line with the most commonly reported studies in small grain cereals, where grain number m^{-2} is the main yield component explaining changes in yield caused by genetic and management factors (Slafer *et al.*, 2005). In agreement with the findings of this study, Kariali and Mohapatra (2007) also supported the theory that grain yield is highly dependent on the number of effective tillers. In the present study, maximum grain yield (6.35 t ha^{-1}) was obtained from Binadhan-8 along with105 kg N from PU + 3 t ha^{-1} POM. Poultry manures application also might have improved soil quality to enhance the yield components and grain yield of rice (Larson and Clapp, 1984; Fagimi and Odebode, 2007). According to Garrity and Flinn (1987), application of poultry manure and N-P-K fertilizer (half) can improve nutrient availability and soil condition for proper plant growth by reducing the loss of nutrients so that the maximum yield can be achieved. Minimum grain yield was related to the BRRI dhan59 with no N application treatment (2.96 t ha^{-1}) because non-application of nitrogen fertilizer decreased yield components and physiological indices. Besides application of USG (fertilizer deep placement) significantly increased yield components and grain yield over PU, other organic sources along with PU except PU with POM. Many authors including Savant and Stangel (1990), Pasandaran *et al.* (1999) and Bowen *et al.* (2004) reported significant yield increases with USG. Yield components including number of effective tillers $plant^{-1}$ and number of grains $panicle^{-1}$ significantly increased as a result of USG application (Table 4). These differences can be ascribed to the slow release of N from USG over the long period with the plant demand.

Our study further confirms that combined application of organic and inorganic N is better than sole inorganic source (PU) on increasing rice yield components and grain yield (Fan *et al.*, 2005; Yaduvanshi and Swarap, 2005; Shah *et al.*, 2010). This may be due to the facts that N is easily available from mineral fertilizer at the early rice growth stage, and organic manures are mineralized at the later rice growth stages. The combined use of organic-N and inorganic- N is better than sole urea for grain, straw and biological yields, because organic manures can reduce N loss (Yaduvanshi and Swarap, 2005) and maintain the supply of N to rice plants for longer time (Fan *et al.*, 2005; Shah *et al.*, 2010). According to Khan *et al.* (2004), Salem (2006), and Antil and Singh (2007), combined application of organic and inorganic N fertilizers can increases the number of panicles m^{-2}, panicle length, panicle weight, number of filled grains $panicle^{-1}$, 1000-grain weight and grain yield of rice. Recently, the combination of organic sources with mineral N fertilizer has attracted much attention from many rice-growing areas of Asia (Myint *et al.*, 2010). Mineral N fertilizer and the mineralization of organic source throughout the growing period could save the rice plants from nutrient stress at any stage, which resulted in maximum yield components and grain yield compared with those in control. Khan *et al.* (2004) and Antil and Singh (2007) reported that organic + inorganic N application is highly beneficial for wetland rice cultivation.

The highest grain yield in Binadhan-8 can be explained by higher concentration of N in grain. N content was lower in straw than in grain. Nitrogen concentration is always higher in the grain of rice than in the stover (Kiniry *et al.*, 2001). Because there are strong relationships among grain N content, straw N content, and grain yield, this indicates that increasing N accumulation in both straw and grain can improve rice yield. Average N uptake were higher with 105 kg N from PU + 3 t ha^{-1} POM and USG than with broadcasting PU and other organic manure along with PU. N seems to be the main limiting element as also observed by Dodermann and Fairhurst (2000). POM is decomposed easily compared to other organic sources and increase N uptake and agronomic efficiency. USG is effective in increasing agronomic efficiency of irrigated rice as compared to the traditional broadcast application of PU in West Africa. Studies conducted in Asia also invariably showed the superiority of USG over PU (Mohanty *et al.,* 1999; Hassan *et al.,* 2002). Deep and point placement of urea in anaerobic soil layer limits the concentration of N in floodwater and in the surface oxidized layer, leading to reduced N losses via runoff, ammonia volatilization and denitrification; the final results are increased agronomic efficiency and improved yield (Kapoor *et al.,* 2008). Rice N uptake and use efficiency also varied among the tested rice cultivars. The genotypic difference in the rooting system and hence nutrient uptake, and grain filling capacity of BRRI dhan29, BRRI dhan59, Binadhan-8 and Binadhan-10 may vary as nutrient transport to the panicles (translocation) during grain filling period. Many authors reported the influence of genotypic traits such as plant type and growth duration on the nutrient use efficiency (Jiang *et al.,* 2004; Duan *et al.,* 2005; Fageria *et al.,* 2010). Recovery efficiency was also significantly increased with application of 105 kg N from PU + 3 t ha^{-1} POM and USG than with broadcasting PU and other organic manure along with PU. The result also indicated that agronomic efficiency and recovery efficiency were significantly associated and suggesting that improving fertilizer N recoveries can also result in increased agronomic efficiency as also reported by Fageria *et al.* (2010).

5. Conclusions

There are wide variations in physiological parameters, as well as growth dynamics, yield and AE among cultivars under different N management. The Binadhan-8 cultivar had the highest yield and was the most N-efficient cultivar due to higher TDM, more grains $panicle^{-1}$ and higher N content than other cultivars. These characteristics are considered important for cultivars with increased yields. Among different inorganic and organic sources used, PU along with poultry manure was found more beneficial in terms of higher yield components and yield. Our results also showed that the response of different rice cultivars to N application was not the same. Significant genetic differences existed among yield increases with N sources, AE and N accumulation in rice. Rational N application, as an important factor affecting rice yield and quality, has always been an important aspect in rice research. Therefore, studies on the differences in N nutrition originated from rice cultivars are urgently required for the purpose of proper fertilization, reduction in resource loss, and protection of the environment.

Conflict of interest

None to declare.

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