Bangladesh Agron. J. 2016, 19(1): 1-10

YIELD RESPONSE AND NITROGEN USE EFFICIENCY OF BORO RICE VARIETIES AS AFFECTED BY DIFFERENT METHODS OF USG AND PRILLED UREA APPLICATION

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Key words: USG and Prilled urea applicator, Nitrogen use efficiencies, BRRI dhan28 and BRRI dhan29

Abstract

An experiment was conducted at the Bangladesh Rice Research Institute (BRRI), Gazipur during Boro season of 2013-14 and 2014-15 to find out the nitrogen use efficiency and yield of boro rice var. BRRI dhan28 and BRRI dhan29 under four N management practices such as application of prilled urea using prilled urea applicator, application of USG (2.7gm) using USG applicator, broadcasting of prilled urea following three splits and a control (without urea). The experimental design was RCBD replicated thrice. BRRI dhan29 with urea broadcasted plots produced higher grain yield (7.38t ha^{-1}) followed by BRRI dhan29 with USG application (6.65 t ha^{-1}). Hand broadcasting with urea fertilizer showed 15.38.5and 2.5, 9.89% higher grain yield than machine application of prilled urea and USG in BRRI dhan28 and BRRI dhan29, respectively. Grain yield showed a significant quadratic response to N fertilization and significant linear response with total dry matter production in both the varieties. Higher total N was uptake from urea broadcasted plots in BRRI dhan29 followed by urea broadcasted from BRRI dhan28. BRRI dhan29 with Prilled urea applicator and BRRI dhan29 with USG treatment uptake intermediate nitrogen. N uptake in grain and total N uptake had a significant linear and quadratic response to N treatment in BRRI dhan28 and BRRI dhan29. Nitrogen use efficiency was higher in BRRI dhan29 compared to BRRI dhan28. Economic analysis showed that rice var. BRRI dhan28 and BRRI dhan29 with urea broadcast had the highest gross return of Tk.145145.00 and Tk. 158310.00 ha^{-1}, respectively. However, the maximum cost (Tk. 151131) was involved for BRRI dhan29 with urea broadcasting, while the minimum with no urea fertilizer application for both the varieties. The highest marginal rate of return (MRR) (Tk.1146) was recorded from BRRI dhan28 with USG application using BRRI applicator.

Introduction

Nitrogen loss processes are due to ammonia volatilization, denitrification, runoff, seepage and leaching which can be improve nitrogen use efficiency for rice production. Deep placement of nitrogen fertilizer into the anaerobic soil zone is a recognized effective method to reduce its volatilization loss from rice field. Urea in the form of USG (Urea Super Granule) has been proved to be superior to granular urea in all aspects. Instead of normal does of 247 kg granular urea, only 160 kg ha^{-1} of USG was required (35% less) even to increase 20% rice yield (Hoque *et. al*., 2013). Depending on agro-climate and nitrogen use, deep-placed USG can save urea fertilizer up to 65% with a 33% increase in grain yields, and up to 50% with 15 to 20% yield increase over the same amount of split-applied nitrogen as prilled urea

(Fatema-Tuz-Zohra et al. 2013). It is reported that USG placement at 6-10 cm depth in wet land rice field can save 30% nitrogen compared to broadcasted prilled urea. Hand placement of USG of 1.8 g to 2.7 g sizes into flood soil resulted in less loss of nitrogen, higher nitrogen recovery and higher yield than conventional nitrogen application method (Hoque *et al*., 2013). USG is presently applied manually. It is placed at a depth of 8 to 10 cm of the soil at the center of 4 consecutive hills of 2 adjacent rows, which is labor intensive, cumbersome and very slow method, i.e. 0.07 to 0.12 ha/workday. Unfortunately, farmers have not been able to be benefited from these findings, primarily because they have no suitable fertilizer placement equipment. Recently BRRI has developed a prilled urea applicator, by which the fertilizer can be placed in a reduced zone of soil and saved about 30-35% without sacrificing grain yield. BRRI prilled urea applicator was designed and developed by considering plant spacing of 20 cm x 20 cm. It is also handy and work efficient. This study was therefore designed to analyze nitrogen use efficiency and yield performance of two popular boro rice varieties, BRRI dhan28 and BRRI dhan29, as affected by different sources of nitrogen and its application methods.

Materials and Methods

Experimental site and soil

The present study was conducted at the experimental field of Bangladesh Rice Research Institute (BRRI), Gazipur situated at $23^0 59´33´´$ N and $90^0 24´19´´$ E at an elevation of 8.4 m from the mean sea level, and is characterized by sub-tropical climate. The soil of the field was clay loam of shallow brown terrace under Madhupur tract (AEZ 28), the experimental field classified as a Chhiata clay loam, hyperthermic Vertic Endoaquept. The chemical properties of the soil are presented in Table 1. The soil of the experimental plot was neutral acidic in nature (P^H =6.3) and poor in fertility status.

The experiment was conducted at BRRI farm, Gazipur during Boro season of 2013-14 and 2014-15 to find out NUEs and response of BRRI dhan28 and BRRI dhan29 under four N management practices such as i) Urea application by Prilled urea applicator ii) USG (2.7 g) application by USG applicator, iii) hand broadcasting of prilled urea with three splits and iv) control (without urea). The experiment was conducted in factorial RCBD design with three replications. Unit plot size was 6m x 4.8 m transplanted with 20cm x 20 cm spacing. BRRI recommended managements were followed for raising seedlings and for other intercultural operations. Fertilizer TSP, M_OP, Gypsum and zinc sulphate were added as basal. Prilled urea and USG (2.7 g) by prilled urea applicator and USG applicator were applied 3 days after planting. Prilled urea top dress were completed in three equal splits, at 15, 35 and 55 DAT. Thirty- eight -days old seedlings were transplanting on 16th and 18th August in 2013-14 and 2014-15, respectively. Grain and straw samples were collected from each plot, oven dried at 65 °C and grains was measured by the standard Micro-Kjeldahl procedure (Bremner and Mulvaney, 1982). N uptake in grain and straw were calculated by following formulae.

$$\text{Nitrogen uptake by grain } (\text{kg ha}^{-1}) = \frac{\%\text{ N in grain} \times \text{Grain yield } (\text{kg ha}^{-1})}{100}$$

$$\text{Nitrogen uptake by straw } (\text{kg ha}^{-1}) = \frac{\%\text{ N in straw} \times \text{straw yield } (\text{kg ha}^{-1})}{100}$$

Agronomic efficiency, physiological efficiency, agro-physiological efficiency, apparent recovery efficiency, and utilization efficiency are calculated by using the formulas described by Fageria *et al*. (1997); Fageria and Baligar (2001). Data on yield and yield components were recorded at maturity. Economic analysis was done to determine the efficiency of different treatments following the procedure of Marginal Rate of Return (MRR) by CIMMYT (1988).

In a combined analysis of data, the interaction of year, N levels, and varieties was non-significant so, pooled analyses was done and means were compared by LSD test.

Results and Discussion

Yield and yield character and total dry matter

Nitrogen and varieties showed insignificant effect on plant height, the individual effect of N on plant height was significant ($p<0.01$). In BRRI dhan28, USG treated plot produced the highest plant height, whereas urea broadcasting produced in BRRI dhan29. BRRI dhan29 produced higher panicle/m^2 compared to BRRI dhan28where maximum panicle was produced by urea hand broadcasting treatment (358) followed by N application by prilled urea applicator (320). In BRRI dhan28 the maximum panicle was produced by urea hand broadcasting (298) followed by USG (288). Thousand grain weight showed insignificant effect on nitrogen and variety interaction. BRRI dhan29 produced the highest grain yield (7.38t ha^{-1}) in urea hand broadcasting plots followed by N application of USG applicator. In BRRI dhan28, similar results were observed. The lowest grain yield was observed from control plots in both varieties. Figure 1 (A) showed grain yield showed a significant quadratic response to N fertilization in both the varieties. Regression analysis showed highest grain yield of BRRI dhan28 and BRRI dhan29 was obtained with urea hand broadcasting treatment (124 kg N ha^{-1}). Singh *et al*. (1998) reported that maximum average grain yield 7.7 t ha^{-1} of lowland rice genotypes was obtained at 150 to 200 kg N $ha^{-1.}$ The relationship of grain yield with total dry matter yield showed highly significant and linear (figure 1 B). Fageria and Baligar (2001) reported that grain yield in lowland rice increased significantly and quadratically with increasing dry matter weight.

Grain harvest index (GHI) and N harvest index (NHI)

Individual effect of N and varieties on GHI was significant but their interaction was not significant. Grain harvest index varied from 0.40 to 0.52 with an average value of 0.48 in BRRI dhan28 and 0.42 to 0.54 with an average value of 0.50 in BRRI dhan29 (Table 4). Figure 2 showed the Kiniry *et al*. (2001) reported that the GHI varied greatly among cultivars, locations, seasons, and ecosystems, ranging from 0.35 to 0.62, indicating the importance of this variable for yield stimulation.

Nitrogen harvest index (NHI) showed insignificant in N and varieties but significant in interaction (Table 5). The NHI values varied from 0.65 to 0.67, with an average value of 0.67 for BRRI dhan28 and from 0.64 to 0.88, with an average value of 0.66 for BRRI dhan29. Fageria and Barbosa Filho (2001) reported that NHI values varied from 0.44 to 0.66 in lowland rice depending on genotypes.

Nitrogen concentration (%) and uptake in grain and straw

The nitrogen and variety interactions in relation to grain N concentration (%) were not significant in BRRI dhan28 and BRRI dhan29 (Table 5). But higher grain N was absorbed in BRRI dhan29 compared to BRRI dhan28. In BRRI dhan29 urea hand broadcasted plot observed higher grain N% followed by USG treated plots. But in BRRI dhan28 USG treated plots accumulated higher grain N% followed by urea hand broadcasted plots. In both the varieties urea hand broadcasted plots accumulated highest straw N. BRRI dhan29 accumulated average highest total N(1.58%) compared to N accumulated from BRRI dhan29 (1.54%) while control plot produced the lowest N%.

N uptake in grain was highest in urea broadcasted plots (79.72 kg ha^{-1}) followed by prilled urea applicator plots in BRRI dhan29 (Table 5). But in BRRI dhan28 highest grain N was uptake from USG treated plots (71.63 kg ha^{-1}) followed by urea hand broadcasted plots. In BRRI dhan29 maximum straw N was uptake from urea hand broadcasted plots followed by plots from prilled urea applicator plots. In BRRI dhan28 highest straw N was uptake from urea hand broadcasted plots followed by USG plots. Highest total N was uptake from urea broadcasted plots in BRRI dhan29 followed by urea broadcasted plots from BRRI dhan28.

N uptake in grain and total N uptake had a significant linear and quadratic response to N treatment from different sources in BRRI dhan28 and BRRI dhan29 (Figure 3A, 3B). N uptake in grain also had a quadric relationship in BRRI dhan28 and in BRRI dhan29 (Figure 3B). In both the varieties grain yield was significantly and linearly related with N uptake in grain (R^2 = 0.96 and 0.99 for BRRI dhan29 and BRRI dhan28) and with total N uptake (R^2 = 0.990and 0.999 for BRRI dhan29 and BRRI dhna28), respectively) (Figure 3A and B), indicating that, in most cases, higher grain yield would be due to higher N uptake. Likewise, an increase of the total N uptake implied an increase on the total dry matter production in both the varieties (Figure 3C). Almost 94.4 and 99.1% of the variation in total dry matter production was explained by N uptake in BRRI dhan29 and BRRI dhan28, respectively. Pamela *et al*. (2009) reported N uptake in grain and total N uptake had a significant quadratic response to N fertilization but total N uptake increased significantly and linearly with N levels.

Nitrogen Use Efficiencies (NUEs)

Effect of N treatment on NUEs was significant in AE, PE, UE and PFP. The highest AE (49) was observed in BRRI dhan28 with N application from USG by USG applicator. The lowest AE (31) was found from BRRI dhan28 with N application from urea broadcasting. The highest PE (128) was observed in BRRI dhan29 with N application from USG by USG applicator while lowers with N application by broadcasting with three splits. The highest APE (84) was observed in BRRI dhan29 with N application from USG by USG applicator. The lowest APE was found from BRRI dhan29 and BRRI dhan28 with N application by broadcasting with three splits. Singh *et al.* (1998) reported an agrophysiological efficiency of about 64 kg grain per kg of N uptake and agronomic efficiency of 37 kg grain per kg of N applied in 20 lowland rice genotypes. USG application by USG applicator and BRRI dhan28 produced the value (83) where as BRRI dhan28 with prilled urea applicator and USG with BRRI dhan29 found the lower recovery efficiency. The highest UE (108) was produced from BRRI dhan29 x USG application by USG applicator and the lowest from BRRI dhan29 urea broadcasted following three splits. PFP was highest in BRRI dhan29 x USG (89) application by USG applicator followed by BRRI dhan28 x USG (84) application by USG applicator treatment. The lowest PFP was observed from urea broadcasting in three splits in both BRRI dhan28 and BRRI dhan29. On average nitrogen use efficiencies was higher in BRRI dhan29 compared to BRRI dhan28.

Economic analysis

Economics analysis was shown in Tables 6, 7 and 8.

Table 6 indicated that the urea broadcasting with three splits with BRRI dhan29 showed the maximum gross return followed by urea broadcasting in BRRI dhan28. Cost dominance analyses (Table 7) showed that cost was highest (Tk. 150831) for the treatment prilled urea broadcasting with BRRI dhan29 and lowest for control plots of both the varieties.. From Table 8, it was observed that the treatment BRRI dhan28× Prilled urea broadcasting and BRRI dhan28×Prilled urea applicator were found cost dominated, where cost is more but gross margin is less than that of other treatments.

The treatment BRRI dhan28 following USG application by USG applicator showed the highest MRR (Tk.1146) and was more profitable than other N treatments as a result interaction of BRRI dhan28 x USG application by USG applicator was more profitable than other N management treatments.

Conclusion

The findings of the study indicated that even though the highest grain yield was recorded from PU application by three splits, the NUE was higher in BRRI dhan28 × USG application plots. USG application by applicator in both BRRI dhan28 and BRRI dhan29 saved 40% nitrogen with intermediate grain yield. Economic analysis by MRR (Marginal rate of return) indicated that BRRI dhan28 x USG application by USG applicator had the highest MMR (1144.86) over other treatments. However, some practical limitations related to accurate calibration and mechanical sophistication need to be resolved to improve further the efficiency of the applicator.

Table 1. Initial soil chemical properties at 0-15 cm soil depth in the experimental plot

Soil properties	Value	SE (±)
Soil pH	6.3	0.19
Organic matter	2.05%	0.27
Total N content	0.09%	0.005
Available phosphorus (P)	11.14 mg kg^{-1} (0.5 M $NaHCO_3$ extracted)	0.094
Exchangeable potassium (K)	0.18 meq/100 g soil (Neutral 1.0 N NH_4OAc extracted)	0.018
Available sulfur (S)	22 mg kg^{-1} [$Ca(H_2PO_4)_2$ extracted]	1.76
Available zinc (Zn)	2.85 mg kg^{-1} (0.01N HCl extracted)	0.08

Table 2. Effect of varieties and nitrogen management on plant height, yield and yield contributing characters during Boro season. BRRI, Gazipur

Nitrogen management	N rate (Kg ha^{-1}	Plant height	Panicle m^{-2}	Grains $panicle^{-1}$	1000-grain	Grain yield

(N)		(cm)			weight	(t ha^{-1})
		BRRI dhan28				
Control	0	87.54	207	75	20.61	2.59
PUA	87	98.67	248	85	21.61	5.47
USG	75	102.12	288	87	23.24	6.30
PUB	124	99.75	298	91	22.09	6.46
Avg.		97.02	260	84	21.88	5.21
		BRRI dhan29				
Control	0	92.70	205	76	21.27	3.11
PUA	87	102.75	320	92	22.07	6.75
USG	75	99.06	317	89	21.79	6.65
PUB	124	102.96	358	98	22.66	7.38
Avg.		99.36	300	89	21.94	5.97
$LSD_{(0.05)}$ for N		5.45	10.61	4.32	ns	0.29
$LSD_{(0.05)}$ for V		ns	7.50	3.05	ns	0.21
$LSD_{(0.05)}$ for N×V		ns	15.00	ns	ns	0.41
CV (%)		4.5	3.1	4.0	4.6	4.2

Control= No Urea, PUA= Prilled urea Applicator, USG= Urea super granule PUB= Urea broadcasting

Table 3. Grain harvest index (GHI) and N harvest index (NHI) of BRRI dhan28 and BRRI dhan29 as influenced by N fertilization from different source and method of application

N source	N rate Kg ha^{-1}	Grain harvest index		N harvest index	
		BRRI dhan28	BRRI dhan29	BRRI dhan28	BRRI dhan29
Control	0	0.40	0.42	0.65	0.68
PUA	87	0.51	0.52	0.67	0.65
USG	75	0.50	0.54	0.69	0.65
PUB	124	0.52	0.53	0.66	0.64
Average		0.48	0.50	0.67	0.66
$LSD_{(0.05)}$ for N		0.22		Ns	
$LSD_{(0.05)}$ for V		0.16		Ns	
$LSD_{(0.05)}$ for N×V		Ns		0.35	
CV (%)		3.7		3.0	

Table 4. Effect of varieties and nitrogen management on N (%) and uptake during Boro season at BRRI, Gazipur

N management (N)	N rate	Nitrogen (%)			Nitrogen uptake (kg ha^{-1})		
		Grain	Straw	Total	Grain	Straw	Total
		BRRI dhan28					
Control	0	0.84	0.46	1.31	22.14	18.02	40.16

PUA	87	1.06	0.51	1.58	60.81	26.82	87.63
USG	75	1.12	0.50	1.63	71.84	30.41	102.26
PUB	124	1.08	0.55	1.64	71.63	35.19	106.83
Avg.		1.02	0.51	1.54	56.60	27.61	84.22
BRRI dhan29							
Control	0	0.91	0.42	1.33	29.85	18.02	47.87
PUA	87	1.07	0.58	1.65	67.73	35.52	103.24
USG	75	1.03	0.54	1.57	61.56	28.11	89.67
PUB	124	1.13	0.64	1.77	79.72	42.39	122.09
Avg.		1.03	0.54	1.58	59.71	31.01	90.72
$LSD_{(0.05)}$ for N		ns	0.43	0.10	8.37	4.35	9.74
$LSD_{(0.05)}$ for V		ns	0.30	ns	ns	3.07	ns
$LSD_{(0.05)}$ for N×V		ns	0.61	ns	ns	6.15	13.77
CV (%)		6.9	6.6	5.2	11.60	12.0	9.0

Table 5. N use efficiencies of different N sources and method of application in variety and nitrogen interaction during Boro 2014 at BRRI, Gazipur

N management	N rate	Nitrogen use efficiencies					
		AE (kg ha^{-1})	PE (kg ha^{-1})	APE (kg ha^{-1})	ARE (%)	UE (kg ha^{-1})	PFP (kg ha^{-1})
BRRI dhan28							
PUA	87	33	102	67	55	72	63
USG	75	49	106	60	83	63	84
PUB	124	31	95	58	54	56	52
Avg.		38	101	62	64	64	66
BRRI dhan29							
PUA	75	42	110	65	64	71	78
USG	124	47	128	84	56	108	89
PUB	0	34	91	58	60	53	60
Avg.		41	110	69	60	77	76
$LSD_{(0.05)}$ for N		5.10	15.72	ns	ns	24.69	3.70
$LSD_{(0.05)}$ for V		Ns	Ns	Ns	Ns	Ns	2.02
$LSD_{(0.05)}$ for N×V		Ns	Ns	Ns	19.56	Ns	5.24
CV (%)		10.0	11.6	18.3	17.4	27.2	2.8

NS= Not significant at the 0.05 probability level.
AE= Agronomic Efficiency, PE= Physiological Efficiency, APE= Agro-physiological Efficiency, ARE= Apparent Recovery Efficiency, UE= Utilization Efficiency, PFP= Partial Factor Productivity

Table 6. Cost return analysis of variety and management

Variety × N management treatment	Variable cost (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
BRRI dhan28×N0	0	65956	65956
BRRI dhan28×PUA	4990	126676	121686

BRRI dhan28×USG	4782	140860	136078
BRRI dhan28×PUB	7438	145145	137707
BRRI dhan29×N0	0	81270	81270
BRRI dhan29×PUA	4823	141195	136372
BRRI dhan29×USG	4900	141696	136796
BRRI dhan29×PUB	7479	158310	150831

Table 7. Cost dominated treatment (Variety x N fertilizer)

Gross margin (Tk. ha^{-1})	Treatments	Variable cost (Tk. ha^{-1})	Cost dominated treatment
150831	BRRI dhan29× PUB	7479	
137707	BRRI dhan28× PUB	7438	*
136796	BRRI dhan29×USG	4900	
136372	BRRI dhan29×PUA	4823	
136078	BRRI dhan28×USG	4782	
121686	BRRI dhan28×PUA	4990	*
81270	BRRI dhan29×N0	0	
65956	BRRI dhan28×N0	0	

Table 8. Marginal rate of return of the applied (Variety x N fertilizer)

Gross margin (Tk. ha^{-1})	Treatments	Variable cost (Tk. ha^{-1})	Marginal variable cost (Tk ha^{-1})	Marginal gross margin (Tk. ha^{-1})	Marginal rate of return
151131	BRRI dhan29× PUB	7479	2579	14035	544
136806	BRRI dhan29×USG	4900	77	424	551
136335	BRRI dhan29×PUA	4823	41	294	717
136218	BRRI dhan28×USG	4782	4782	54808	1146
81470	BRRI dhan29×N0	0		15314	
66083	BRRI dhan28×N0	0			

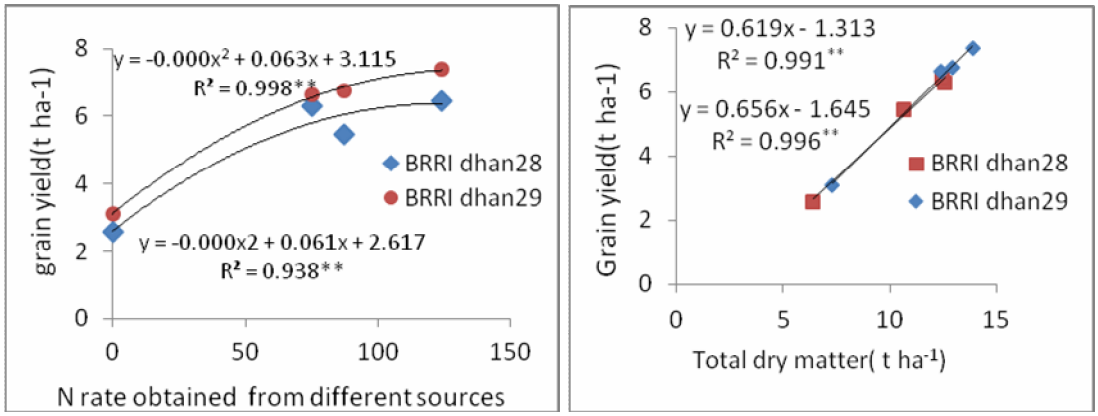

Fig.1. Relationship between grain yield and N rate obtained from different sources (Fig. 1A) and total dry matter and grain yield of rice varieties BRRI dhan28 and BRRI han29 (Fig. 1B),

** Significant at the 0.05 probability level

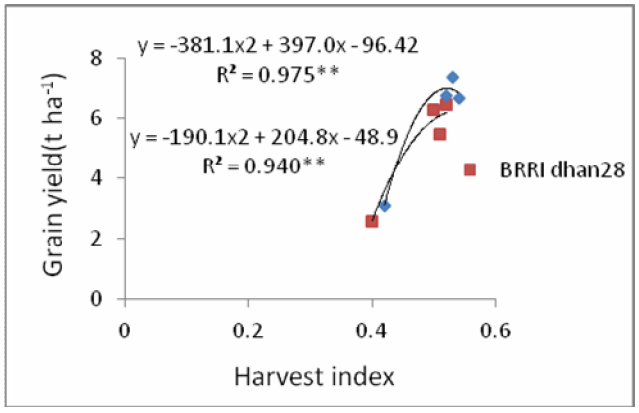

Fig. 2. Relationship between harvest index and grain yield

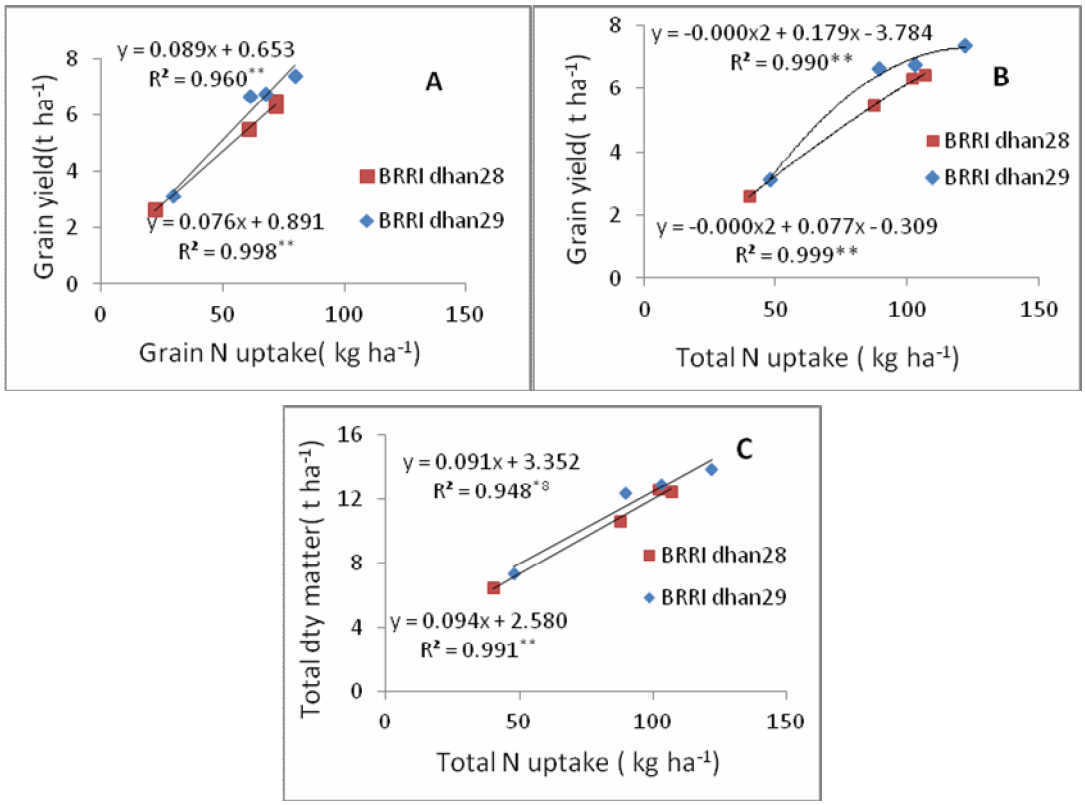

Fig. 3. Relationships between (A) grain N uptake and grain yield, (B) total N uptake and grain yield, and (C) total N uptake and total dry matter production of rice varieties BRRI dhan28 and BRRI dhan29.

** Significant at the 0.05 probability level

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