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Integrated Nitrogen Management on Nutrient Contents, Uptake and Use Efficiency of BRRI Dhan29

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Authors' contributions

This work was carried out in collaboration between all authors. Author MSA designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author MMR managed the analyses of the study. All authors managed the literature searches, read and approved the final manuscript.

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ABSTRACT

A field experiment was performed with BRRI Dhan 29 at Field Laboratory of Soil Science, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. The effects of organic (cowdung) and inorganic (urea) amended N fertilizers were evaluated for NPKS contents and uptakes in grain and straw, and also for observing N use efficiency. Randomized complete block design was set for seven treatments based on recommended dose of N (RDN) @ 150 kg ha^{-1} using cowdung and/or urea alone or their combinations. The NPK contents as well as their uptake in grain and straw were significantly affected due to different treatments while S content was insignificant. The application of recommended dose of N from urea (T_1) showed highest N content in grain (1.11%) and straw (0.71%) which was closely followed by the treatment T_6 (20% RDN from

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cowdung + 80% RDN from urea). The maximum P content was found from the grain and straw of T_6 treatment whereas a significant increase in the P, K and S contents were noted due to combined application of N from cowdung and urea. The NPKS uptake of grain and straw as well as total uptake (107.60 kg ha^{-1} N, 27.84 kg ha^{-1} P, 71.36 kg ha^{-1} K and 25.63 kg ha^{-1} S) were recorded maximum in T_1, followed by T_6. The treatment T_1 yielded maximum apparent N recovery efficiency (45.06%) and agronomic N use efficiency (19.60 kg kg^{-1}) while the maximum physiological N use efficiency (43.55 kg kg^{-1}) was found in T_6. Results also suggested that the application of lower doses of urea N with higher doses of cowdung N were not useful for the N recovery due to low N supplying potentiality of manures in a single cropping season. However, the incremental rates of urea N upto 80% along with 20% cowdung N effectively increased the recovery of N in all the parameters of N use efficiency and should be applicable to optimize the need for N requirement and build up a good soil health.

Keywords: Cowdung; urea; NPKS; uptake; nitrogen use efficiency; rice etc.

1. INTRODUCTION

Rice is the principal carbohydrate supplying food crop for the people of Bangladesh. The country is the fourth-largest rice producer in terms of area and production among the rice growing countries [1]. The agriculture in Bangladesh is mainly dominated by intensive rice cultivation in favor of its geographical and agroclimatic conditions but the soils experience multiple nutrient deficiencies over the years. In intensive cropping system, continuous use of high levels of chemical fertilizers usually with high N inputs lead to nutritional imbalance in soil, decline crop productivity and reduced N use efficiency as well as increased N loss to the environment [2]. The farmers of Bangladesh use only about 172 kg nutrients ha^{-1} annually (132 kg N, 17 kg P_2O_5, 17 kg K_2O, 4 kg S, 2 kg Zn + B), as against the crop removal of about 250 kg ha^{-1}[3] and they are mainly concerned about the widely used urea N fertilizer for rice cultivation. A recent estimate also showed that rice (HYV) uptake about 108 kg N, 18 kg P, 102 kg K and 11 kg S ha^{-1} from soils [4]. Considering the ecological and environment concerns over the increased and indiscriminate uses of inorganic fertilizers have continued to stimulate research on uses of organic materials as sources of nutrients [5]. Use of organic matter as a source of plant nutrients increases the fertilizers use efficiency and makes soil living. Nitrogen is characteristically the nutrient of most concern because of its enormous impact on cereal crops yields including rice. Manure is one of the most important N sources in paddy rice systems although it poses a countless challenge in meeting rice N requirement. Generally, manure amended rice systems historically has been used for its N use efficiency improvement and animal waste recycling. Nitrogen release from manure is relatively slow compared to chemical N fertilizer like urea, and may mismatch the N requirement for rice growth, especially during the mid or late rice growth period. Many agroecologists have focused that manure should be applied as basal fertilizer and combined with urea or other fast released chemical N fertilizers as topdressing [6,7]. The split application of N might provide a compromise between traditional and modern production systems which would improve both soil micro environment and N use efficiency [8]. So, selection of adequate amounts of N from organic and inorganic sources is one of the best solutions for sustainable rice cultivation. Cowdung is a potential source of organic manure in Bangladesh and extensively used in the vegetables cultivation. The application of cowdung in rice fields as a nutrient source may reduce the requirement of chemical nitrogenous fertilizers, but the question has not been examined sufficiently for a wide array of soil and variety. It is also important to look beyond the immediate crop needs of highly demanding N nutrition during growth in order to optimize the uptake and use efficiency from organic and inorganic sources. Therefore, the present study was carried out to evaluate the effects of nitrogen either from urea or cowdung along with their combinations on the changes of nutrient contents, uptake and use efficiency by BRRI Dhan 29.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil

The experiment was set up at the Soil Science Field Laboratory, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the boro season (January to May 2015). The site was under the Old Himalayan Piedmont Plain (AEZ 1) and the soils belong to

Ranisankail series having sandy loam texture. The soil was characterized by slightly acidic in nature (pH = 6.56) with OC (0.34%), total N (0.02%), available P (11.24 ppm), exchangeable K (0.13 me 100^{-1} g), exchangeable Ca (1.26 me 100^{-1} g), exchangeable Mg (0.51 me 100^{-1} g), available S (35.47 ppm), available Zn (0.74 ppm), available B (0.23 ppm), and CEC (5.5 me 100^{-1} g).

2.2 Treatments and Design

There were seven treatments consisting different combinations of recommended dose of N (N_{150}) either from organic and/or inorganic sources (cowdung and urea used as organic and inorganic sources, respectively). The treatment combinations were T_0: Control (no nitrogen), T_1: 100 % RDN from urea, T_2:100% RDN from cowdung, T_3: 80% RDN from cowdung + 20% RDN from urea, T_4: 60% RDN from cowdung + 40% RDN from urea, T_5: 40% RDN from cowdung + 60% RDN from urea, and T_6: 20% RDN from cowdung + 80% RDN from urea. All the treatments also received recommended doses of other nutrients on soil test basis ($P_{20}K_{65}S_{18}Zn_{1.3}$) through TSP, MoP, Gypsum and $ZnSO_4$, respectively. The treatment wise required nitrogen from cowdung was calculated on the basis of 0.78% N content of well decomposed dried cowdung. The experiment was laid out in the randomized complete block design (RCBD) with four replications following the net plot size of 15 sq. m (5m x 3m). The full doses of cowdung as per treatments were added 15 days before transplanting. The full doses of TSP, MoP, Gypsum, Zinc sulphate were applied during the final land preparation. Urea was applied in three equal splits: the first split after 7 days of transplanting, the second split as top dressing after 30 days of transplanting while third one after 60 days of transplanting (before panicle initiation stage). The standard procedure was followed for transplantation as well as other intercultural operations [9]. After recording the yield, grains and straw samples from each unit plot were collected for analysis of nutrient contents.

2.3 Analyses of Nutrient Contents in Plant Samples

2.3.1 Preparation of plant samples

Both the grain and straw samples were dried in an oven at 60°C for 24 hours and then grounded by a grinding mill. The prepared samples were kept in desiccators until analyses.

2.3.2 Determination of total nitrogen

Well ground 0.1 g oven dry samples were taken in kjeldahl flasks containing 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 100: 10: 1), 3 ml 30% H_2O_2 and 5 ml conc. H_2SO_4. The flasks were swirled and allowed to stand for 10 minutes and heated at 380 °C until the digest became clear and colourless. After cooling, the content was diluted with water and made the volume of 100 ml. Then, 40% NaOH was added with the digests for distillation and the evolved ammonia was trapped in 4% H_3BO_3 solution having 5 drops of the mixed indicator [bromocressol green ($C_{21}H_{14}O_5Br_4S$) and methyl red ($C_{10}H_{10}N_3O_3$) solution]. Finally, the distillates were titrated with the standard 0.01 N H_2SO_4 until the colour changed from green to pink [10]. A reagent blank was also prepared in the same way for accuracy in analysis.

2.3.3 Determination of P, K and S

Plant samples (0.5 g) were digested by using 10 ml of diacid mixture (HNO_3: $HClO_4$ = 2: 1) into 100 ml kjeldahl flasks. After leaving for overnight, the flasks were heated slowly upto 200 °C until the contents became sufficiently clear and colourless. After cooling, the digests were diluted by distilled water to make 50 ml in a volumetric flask. The digests were then filtrated and used for P, K and S determination. 1 ml digest from grain samples and 2 ml digests from straw samples were used for P determination followed by developing blue colour of phosphomolybdate complex using $SnCl_2$. The absorbance was measured at 660 nm wave length in spectrophotometer and available P was calculated with the help of a standard curve [11]. In case of K determination, 5 ml digest for grain and 2 ml for straw were taken and diluted to 50 ml volume for getting the desired concentration because of the absorbance of samples could be measured within the range of standard solutions. The absorbances were finally measured by flamephotometer. The content of S in the digest was determined by adding acid solution followed by forming turbidity using $BaCl_2$. The intensity was measured by spectrophotometer at 420 nm wave length [12].

2.4 Nutrient Uptake

Nutrient uptake was calculated from the measured yield and nutrient contents (grain and straw), and expressed by the formula stated below:

$$\text{Uptake (kg ha}^{-1}) = \frac{\text{Yield (kg ha}^{-1}) \times \text{Nutrient content (\%)}}{100}$$

2.5 Nitrogen Use Efficiency

Nitrogen use efficiency (NUE) generally accounts for the quantity of N accumulated in the plant, showing the N uptake efficiency and the quantity of N utilized in grain production or the N utilization efficiency of the plant to applied N. The NUE components: apparent N recovery efficiency (ANRE), physiological N use efficiency (PNUE), and agronomic N use efficiency (ANUE) were calculated with the following expressions [13]:

$$\text{Apparent N recovery efficiency (\%)} = \frac{(N_f - N_c) \times 100}{NA}$$

$$\text{Physiological N use efficiency (kg kg}^{-1}) = \frac{G_f - G_c}{N_f - N_c}$$

$$\text{Agronomic N use efficiency (kg kg}^{-1}) = \frac{G_f - G_c}{NA}$$

where, N_f and N_c refer to the total above ground plant dry matter-N content (kg ha^{-1}) in the fertilized and control (nonfertilized) plots, G_f and G_c refer to grain yield (kg ha^{-1}) in the fertilized and control plots, and NA is the amount of fertilizer-N in kg ha^{-1} applied.

2.6 Statistical Analyses

All the collected data were analyzed for ANOVA with the help of the computer package program MSTAT. The differences among the treatment means were evaluated by the Duncan's New Multiple Range Test (DMRT) as outlined by [14].

3. RESULTS AND DISCUSSION

3.1 Nutrient Contents in Grain and Straw of BRRI Dhan 29

3.1.1 Nitrogen(N)

The N contents in rice grain and straw were significantly influenced by the application of organic and inorganic sources of N over control, ranged from 0.74 to 1.10% in grain and 0.41 to 0.71% in straw (Table 1). The highest N content (1.11%) in grain was observed in the treatment T_1 (application of N_{150} through urea) which was statistically parallel to treatment T_5 and T_6. The lowest (0.83%) grain N was noted in the treatment T_0 (control) where no N fertilizer was applied. So, use of inorganic fertilizers increased the N content in the rice grain markedly. It was noticed that the influence of T_1 on the straw N contents was statistically superior to the other treatments. An increasing tendency of N contents both in grain and straw was noted from the treatments receiving incremental doses of urea N along with cowdung amended N compared to sole cowdung treated plot. The effect of 80% urea N along with 20% cowdung N was more pronounced in both grain and straw N contents than other combinations. It was also conceivable that the N content was comparatively higher than that of straw. Application of S fertilizer increased the N content in straw. A significant increase in N content in rice grain and straw due to application of organic manure and fertilizers have also been reported by many investigators [15,16].

3.1.2 Phosphorus(P)

The P contents in grain and straw of BRRI Dhan 29 were significantly varied by different treatments under the study (Table 1). In case of grain, the maximum P content (0.25%) was recorded in the treatment T_6 and the minimum was found in the treatment T_0 (control). From the Table 1, it was clear that the treatment T_6 was statistically different from only control treatment. The results pinpointed that P supplied to all the treatments in same amounts but the increased amount of P content was found in the T_6 than that of the T_1 treatment. This might be due to the utilization of cowdung N on positive governance on the P content in grain. On the other hand, straw P content was almost lower than grain and varied from 0.12 to 0.21%. The highest P content (0.214%) was observed in the treatment T_6 and was statistically similar to those measured in the treatments T_1, T_2,T_3,T_4 andT_5 having the values 0.21, 0.16, 0.18, 0.19 and 0.20%, respectively. Application of organic N as cowdung either alone or in association with decremental rates of the advocated inorganic N as urea caused pronounced effect in increasing the straw P content. Increase in P contents both in rice grain and straw increased due to application of cowdung, poultry manures and chemical fertilizers were reported by other researches [17,18].

3.1.3 Potassium(K)

The contents of K in grain and straw were governed profoundly by the different treatments (Table 1). The highest content of K in grain (0.31%) was obtained in the treatment T_5, which was statistically similar to that observed in the treatment T_1,T_4 and T_6. The treatment T_0 (control) produced the lowest (0.28%)grain K content, which was statistically dissimilar to all other treatments. The highest K content (0.88%) in straw was obtained in the treatment T_1 which was statistically similar to all other treatments except control. It was also observed that the K content in straw was higher than that of grain in all the treatments. The incorporation of increased doses of cowdung amended organic N combined with reduced doses of inorganic urea N showed better impact in increasing K contents both in grain and straw. K contents in rice grain increased considerably due to application of sulphur fertilizer. [19] reported that K contents in grain and straw were increased due to beneficial effects from combined application of organic and inorganic fertilizers.

3.1.4 Sulphur(S)

Results in the Table 1 indicated that S contents in both grain and straw were statistically insignificant ($p > 0.05$) due to different treatments. The highest value of S contents in grain (0.07%) was obtained from both T_1 and T_6 treatments while the lowest was noted in T_0 (control). All the treatments caused an increasing effect of S content of rice grain. In straw, S contents ranged from 0.03 to 0.05%. The treatment T_0 (control) had the lowest value of S content (0.03%). It was also revealed that the S contents in grain were higher than that of straw in all the treatments. The incorporation of organic N combined with reduced doses of inorganic urea N showed better performance in increasing S contents both in grain and straw over the control. [20]reported that application of manures and fertilizers increased the S content both in grain and straw of rice.

3.2 Nutrient Uptake by Grain and Straw of BRRI Dhan 29

3.2.1 Nitrogen(N)

Significant effects on N uptake by BRRI Dhan 29 were found in rice grain and straw (Table 2). The N uptake by grain ranged from 21.87 to 64.40 kg ha^{-1}. The effect of T_1 treatment receiving 100% N from urea on N uptake by grain was statistically superior to all other treatments but alliance with the treatment T_6. From Table 2, it was clear that the uptake of N by grain by using 80% N from urea with 80% cowdung amended N exerted greater effect compared to cowdung N alone or other combinations. Application of S increased the N uptake by grain considerably. A significant linear relationship was observed between grain yield and grain N uptake (Fig. 1a). The N uptake in grain from different treatments ranged from 18.14 to 43.24 kg ha^{-1}. The uptake of N was found maximum (43.24 kg ha^{-1}) in the T_1 treatment and was statistically superior to the rest of treatments. It was noted that N uptake by grain was higher than that of straw. The total N uptake varied distinctly and ranged from 40.10 to 107.60 kg ha^{-1}. The highest total N uptake (107.60 kg ha^{-1}) was found in the treatment T_1, which was statistically similar to T_6 treatment with total N uptakes of 103.82 kg ha^{-1}. The lowest total N uptake (40.10 kg ha^{-1}) was manifested in the treatment T_0 (control) that was statistically inferior to all other treatments and followed by the T_2 treatment. The total N uptake for the treatments ranked in the order of $T_1 > T_6 > T_5 > T_4 > T_3 > T_2 > T_0$. [18] and [21] reported that application of N from manures and fertilizers significantly increased the N uptake both in grain and straw of rice.

3.2.2 Phosphorus(P)

There was a significant variation in P uptakes by rice grain and straw due to different treatments. P uptake ranged from 4.32 to 14.85 kg ha^{-1} in grain and 5.21 to 12.99 kg ha^{-1} in straw. The highest uptake in rice grain was found in the treatment T_1 and was significantly similar to T_6 with the value of 12.80 kg ha^{-1}. The lowest uptake of P was noted in the control (T_0). From the Fig. 1b, it was observed that grain yield was significantly linked with grain P uptake. The highest P accumulation by straw (12.99 kg ha^{-1}) was manifested in the treatment T_1 whereas the lowest (5.21 kg ha^{-1}) was recorded in the treatment T_0. The treatment T_1 was closely succeeded by the treatments T_4, T_5 and T_6.However, all the treatments significantly increased the P uptake over control (T_0). The total uptake was also different due to different treatments (9.52 kg ha^{-1} in T_0 and 27.84 kg ha^{-1} in T_1 (Table 2). The treatment T_1 was statistically different from all other treatments on total P uptake but followed by those recorded in the treatments T_5 and T_6. The application of incremental doses of inorganic N performed better in increasing P uptake compared to organic source alone. Similar result was also experienced by other studies [15,17,18].

3.2.3 Potassium(K)

The K uptake ranged from 8.54 to 17.84 kg ha^{-1} in grain and 30.26 to 53.53 kg ha^{-1} in straw

Table 1. Effects of organic and inorganic sources of N on the nutrient contents in grain and straw of BRRI Dhan 29

Treatments	% N		% P		%K		% S	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_0	0.74e	0.41d	0.15b	0.12b	0.28d	0.70b	0.05	0.03
T_1	1.11a	0.71a	0.24a	0.21a	0.30ab	0.88a	0.07	0.05
T_2	0.91d	0.51c	0.24a	0.16ab	0.29cd	0.80a	0.06	0.03
T_3	0.98c	0.59b	0.24a	0.18a	0.29bcd	0.83a	0.06	0.04
T_4	1.04b	0.60b	0.24a	0.19a	0.30abc	0.82a	0.07	0.04
T_5	1.06ab	0.62b	0.24a	0.20a	0.31a	0.86a	0.07	0.04
T_6	1.09a	0.64b	0.25a	0.21a	0.30abc	0.86a	0.07	0.04
CV (%)	2.83	6.66	7.45	7.88	7.43	6.45	2.82	6.89

In a column figure(s) having different letter(s) differed significantly at 5% level of significance by DMRT (P = .05)

Table 2. Effects of organic and inorganic sources of N on the N and P uptakes by grain and straw of BRRI Dhan 29

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
T_0	21.87d	18.14e	40.01f	4.32d	5.21d	9.52 e
T_1	64.40a	43.24a	107.60a	14.85a	12.99a	27.84a
T_2	27.13cd	25.37d	52.50e	6.49cd	8.15c	14.63d
T_3	33.24c	31.07c	64.30d	7.52bc	9.49bc	17.01d
T_4	41.78b	34.56bc	76.33c	9.39b	11.04b	20.43c
T_5	43.89b	36.31b	80.21c	9.83b	11.23b	21.06bc
T_6	61.21a	42.61a	103.82a	12.80a	11.30b	24.10b
CV (%)	2.52	9.13	8.50	7.53	5.36	3.37

In a column figure(s) having different letter(s) differed significantly at 5% level of significance by DMRT (P = .05)

Table 3. Effects of organic and inorganic sources of N on the K and S uptakes by grain and straw of BRRI Dhan 29

Treatments	K uptake (kg ha^{-1})			S uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
T_0	8.54d	30.26d	38.81e	8.70e	0.86d	9.57e
T_1	17.84a	53.53a	71.36a	23.95a	1.68a	25.63a
T_2	8.48d	39.98a	48.47d	10.07de	1.12cd	11.19de
T_3	9.85cd	43.89bc	53.74cd	12.04d	1.25bc	13.29d
T_4	12.23bc	46.80ab	59.03bc	15.45c	1.46ab	16.91c
T_5	12.90b	49.67ab	62.58b	16.19c	1.49ab	17.68c
T_6	14.87b	48.24ab	63.11b	19.56b	1.41abc	20.96b
CV (%)	4.77	9.61	7.51	3.37	8.96	2.92

In a column figure(s) having different letter(s) differed significantly at 5% level of significance by DMRT (P = .05)

(Table 3). The highest uptake by grain (17.84 kg ha^{-1}) was found in the treatment T_1, which was statistically dissimilar with the treatments T_4,T_5 and T_6 that gave 12.23, 12.90 and 14.87 kg ha^{-1} K, respectively. Nonetheless, it was worthwhile to mention that the grain yield was significantly correlated with grain K uptake (Fig. 1c). In case of straw, the highest value (53.53 kg ha^{-1}) was appeared in the treatment T_1 and succeeded by that observed in the treatments T_4,T_5 and T_6. However, all the treatments significantly enhanced the uptake over control (T_0). The total uptake was also shaped significantly due to different treatments and ranged from 38.81 to 71.36 kg ha^{-1} (Table 3). The treatment T_1 had the highest total uptake of K (71.36 kg ha^{-1}) which was statistically identical to T_4,T_5 and T_6 treatments. The least total uptake (38.81 kg ha^{-1}) was noted in the treatment T_0 (control). It was obvious that K uptake by grain was much less than that of straw and the results were in agreement with [22].

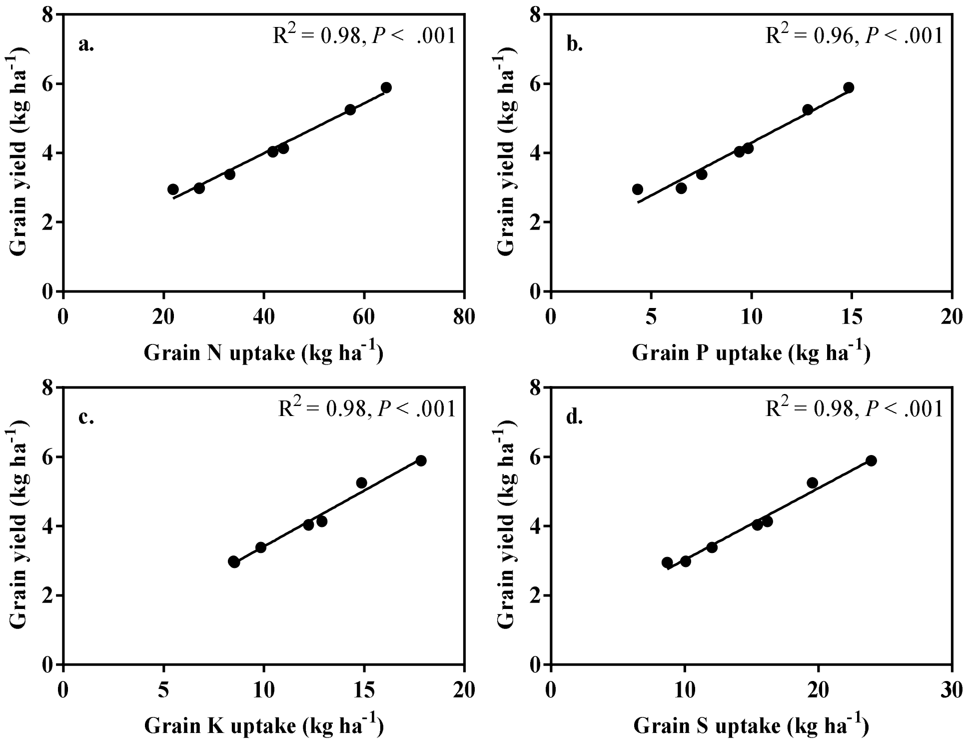

Fig. 1. Relationship between the grain yield of BRRI Dhan 29 and grain nutrient uptake; grain N uptake (a), grain P uptake (b), grain K uptake (c) and grain S uptake (d)

3.2.4 Sulphur (S)

Table 3 showed significant effects on S uptake in rice grain and straw as well as in total uptake. All the applied treatments significantly influenced on S uptake by grain over the control treatment (T_0) but the effect of T_1 treatment on S uptake by grain was statistically superior and different from all other treatments. A linear relationship between grain yield and grain S uptake was observed and presented in the Fig. 1d. The S uptake in straw from different treatments ranged from 0.86 to 1.68 kg ha^{-1} and found maximum (43.24 kg ha^{-1}) in the T_1 treatment that was statistically parallel to T_4, T_5 and T_6 treatments. It was noted that S uptake by grain was higher than that of straw. The highest total S uptake (25.63 kg ha^{-1}) was noted in T_1 treatment, which was statistically different from all other treatments and followed by T_6 treatment with the value of 20.96 kg ha^{-1}. The lowest total S uptake (9.57 kg ha^{-1}) was observed in the treatment T_0 that was statistically inferior to all other treatments. Similar findings were also reported by many researchers [21,23].

3.3 Nitrogen Use Efficiency (NUE) of BRRI Dhan 29

The response of the N use efficiency (NUE) components due to organic and inorganic sources of N varied as presented in Fig. 2. The apparent N recovery efficiency (ANRE) by BRRI Dhan 29 ranged from 8.33% to 45.06% (Fig. 2a). The data clearly indicated that the maximum apparent N recovery (45.06%) was obtained with the 100% recommended doses of N from urea (T_1). However, similar results of ANUE (42.54%) was also found in T_6. The reasons for high recovery of applied N could be the split application of urea in rice field that resulted in continuous supply of readily available N from urea throughout the growth period of rice. It was also found that lower rates of urea N with higher rates of cowdung amended N were not useful for the N recovery but the incremental rates of inorganic N with lower rates of organic N improve the recovery of N. Similar observation was also reported in other literatures [24,25]. On the contrary, the physiological N use efficiency (PNUE) varied from 2.40 to 43.55 kg kg^{-1} (Fig.

2b). The peaked value in respect of PNUE was noted in the treatment T_6 (43.55 kg kg^{-1}) followed by the treatment T_1 with the value of 43.50 kg kg^{-1}. Agronomic N use efficiency (ANUE) is a term used to represent the response of rice plant in terms of grain yield to N fertilizer. The range of ANUE varied from 0.20 to 19.60 kg kg^{-1} with highest value in T_1 treatment and lowest in T_2. This result suggested that application of recommended doses of N through inorganic sources lead to efficient uptake and utilization of applied N. It was also clear that the sole application of N through organic sources had the lowest ANUE. However, the ANUE increased when reduced doses of organic N sources were applied along with incremental doses of inorganic N from urea. These results were also in agreement with the other researchers [18,26].

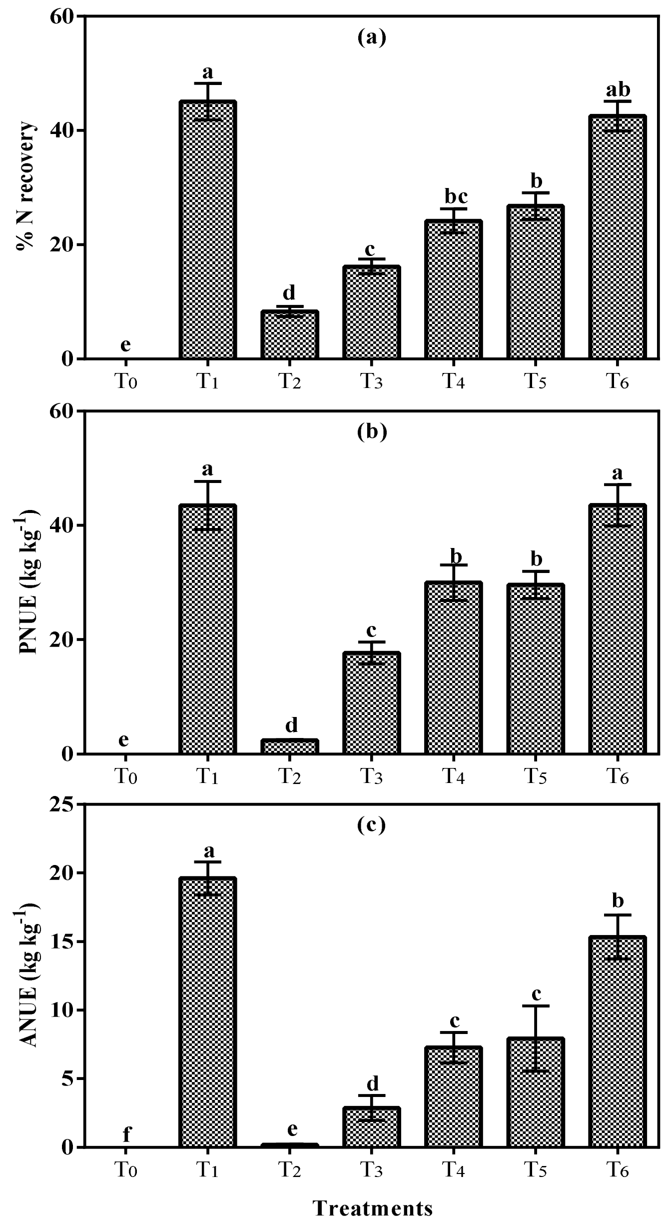

Fig. 2. Effects of organic and inorganic sources of nitrogen on apparent nitrogen recovery efficiency (a), physiological nitrogen use efficiency (b), and agronomic nitrogen use efficiency (c) of BRRI Dhan 29. Data are means ± S.E.M. (*n* = 4)

4. CONCLUSION

The present study was conducted to investigate the effects of different ratios of N supplied either from cowdung and/or urea or from their combinations on the changes in nutrient contents, uptake and use efficiency by BRRI Dhan 29. The results indicated that nutrient contents and uptake by the grain and straw of the crops ranked top when applied with sole application of inorganic N (urea), followed by the application of N in mixture (80% N from urea + 20% N from cowdung), while no nitrogen application (control) ranked in the bottom. The performance of 40, 60, 80, 100% manure amended N level showed a relatively little comparable effect on nutrient contents and corresponding uptake. However, there was an obvious contribution of N supplied from cowdung on N use efficiency components, though the application of recommended dose of inorganic N from urea performed better in this case. Further research should be focused on multiple locations with different paddy soils and climate to scale up the optimum requirement.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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