Effects of Integrated Use of Prilled Urea, Urea Super Granule and Poultry Manure on Yield of Transplant Aus Rice and Field Water Quality

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Abstract: A field experiment was carried out to investigate the effects of prilled urea (PU) and urea super granule (USG) alone and their combinations with poultry manure (PM) on growth and yield of transplant Aus rice (cv. BR 21) and field water quality. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments were T1: Control (no fertilizer), T2: (165 kg N ha-1 from prilled urea), T3: (119 kg N ha-1 from USG), T4: (82 kg N ha-1 from prilled urea + 3 t ha-1 poultry manure) and T5: (56 kg N ha-1 from USG + 3 t ha-1 poultry manure). The highest grain (3.19 tha-1) and straw yields (4.51tha-1) were obtained from treatment T5 (56 kg N ha-1 USG + 3.0 t ha-1 poultry manure) while the lowest grain (1.99 tha-1) and straw yield (3.38 tha-1) were recorded for T1 (control). Treatment T3 (119 kg N ha-1 from USG) performed better than T2 and T4 indicating the superior effect of USG over prilled urea. The N, P, K and S contents in the grain and straw and their total uptake were influenced profoundly due to application of PU, USG alone or in combination with poultry manure. In case of rice field water quality, the USG generated available NH4-N slowly but spontaneously over the entire growth period compared to prilled urea indicating a beneficial role of USG. The other properties of field water like pH, EC were also influenced by the application of prilled urea, USG and poultry manure. The overall results indicate that application of USG in combination with poultry manure was more effective in producing higher rice yield and at the same time reduce water pollution.

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Key words: Urea super granule, prilled urea, poultry manure, water properties, rice yield, N use efficiency.

1. Introduction

Rice is a staple food for more than 3 billion people in the world (IRRI 2005). Rice is also the main food crop of Bangladesh and it covers about 80% of the total cropped area of the country (AIS, 2008). But the grain yield per hectare is still low compared to other major rice growing countries of the world. One of the main contributing factors influencing the yield of rice is judicious application of fertilizers. Nitrogen fertilizer is one of the key inputs for rice production and urea is the most common nitrogen fertilizer used in rice production in Bangladesh. Annual urea requirement of the country is about 28 million ton of which 50% is met by domestic production. The rest of the urea needs to be imported by spending a large amount of foreign currency (BBS, 2008). The soil nitrogen content of the country is also very low due to warm climate accompanied by extensive cultivation practices with little addition of manures in the crop fields. As a result, most of the flooded rice fields experience a shortage of nitrogen, so the addition of costly nitrogen fertilizers should always be done to maintain its availability. The nitrogen efficiency especially of urea fertilizer is very low (30-35%) in rice cultivation (IFDC, 2007). In spite of that, the farmers use urea fertilizer by broadcast method during cultivation and most of the applied fertilizers are lost through volatilization, denitrification, run-off and leaching. The use of USG and organic manure has often been advocated to minimize nitrogen losses because organic manures act as a great source of plant nutrients especially of N, P, K and S, and also prevents leaching loss of the nutrients. Organic manure also plays a vital role in improving physical, chemical and biological properties of the soil and ultimately enhances crop production. Wani *et al.* (1999) revealed that urea super granule @ 120 kg N ha^{-1} was the best in producing the yield and yield attributes of rice. Iqbal (2011) found that during paddy growth, nitrogen losses from different nitrogen treatments varied 2.82-5.07% application of the urea compared to USG. Vennila *et al*. (2007) reported that 75% recommended dose of N fertilizer + 25% N as poultry manure increased growth, yield attributes and yield, and nutrient uptake of rice higher soil available organic carbon, nitrogen and phosphorus.Proper identification and management of soil fertility problems are prerequisites for boosting crop production and sustaining higher crop yields over a long period of time. In general, integrated use of organic and inorganic nitrogen is the best combination of available nitrogen management techniques, which would facilitate achieving the required productivity and sustainability by efficient use of soil and applied nitrogen (Pushpanathan *et al*., 2004). Lin. *et al.* (2009) concluded that application of mixed mineral-fertilizer-N and organic-fertilizers-N had a better effects on the yields of rice grains and N use efficiency could be significantly increased compared with the single application of mineral nitrogen fertilizer. Addition of poultry manure from 0 to 6 t ha^{-1} with 0, 25, 50 and 100 per cent recommended dose of fertilizer increased the grain yield of rice and nutrient uptake (Suvarnalatha *et al*., 2003). But, there is lack of data in the literature on the integrated use of prilled urea, USG, and poultry especially on yield and nutrient uptake of rice as well as their effects on field water quality,. Hence, this study was undertaken to evaluate the effects of prilled urea and USG alone or in combination with poultry manure on N use efficiency, and yield of rice as well as on the field water quality.

2. Material and Methods

Experimental site, soil and climate

Table -1. Physical-chemical properties of soil of the experimental plots

Soil properties	Analytical data
Sand	18%
Silt	78%
Clay	4%
Textural class	Silt loam
Soil pH	6.71
CEC(me/100g soil)	15.00
Organic carbon (%)	1.678
Total nitrogen (%)	0.17
Available P (ppm)	10.55
Exchangeable K (meq/100g soil)	0.14
Available S (ppm)	14.25

The experiment was carried out at the Soil Science Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh. The experimental area is located at 24075/ N latitude and 90050/ E longitudes at the elevation of 18 m above sea level. The soil belongs to the Sonatala soil series of non-calcareous dark grey floodplain soils under the Agro ecological zone (AEZ) of Old Brahmaputra Floodplain and the soil order inceptisol. The soil was silt loam with 1.68 %OC and pH 6.71 (Table 1).

Treatments and crop culture

The rice variety BR 21 was used as the planting materials in the experiment. The treatments used were; T_1: Control (no fertilizer), T_2: (165 kg N ha^{-1} from prilled urea), T_3: (119 kg N ha^{-1} from USG), T_4: (82 kg N ha^{-1} from prilled urea + 3 t ha^{-1} poultry manure) and T_5: (56 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. All treatment plots also received P, K, S and Zn fertilizers which were applied at the rate of 50, 75, 45 and 2.6 kg ha^{-1}, respectively as a basal dose during the final land preparation. Prilled urea was applied in two equal splits. The first dose of urea (PU and USG) was applied at 12 days after transplanting (DAT), the second dose of prilled urea was added as top dressing 36 days after transplanting (active tillering stage). One USG of 0.9 g size was employed for every four hills. The granules were deep placed in puddled soil by hand and leveled immediately after placement. Poultry manure was incorporated in two plots ($T_{2,}$ T_3) at 3t ha^{-1} as per the treatment at 7 days before transplanting of the rice seedlings. The PM was mixed thoroughly with the soil at the time of final land preparation. Thirty five-days-old rice seedlings were carefully uprooted from a seedbed. The seedlings were placed at a spacing of 20 cm × 20 cm. The field was irrigated to maintain 6 cm of water above the soil surface for water sample collection and as per necessity of the crop. The experimental plots were infested with some common weeds, which were removed from the field by manual weeding during the entire period of the experiment.

Water sampling and analysis

The surface water in the rice field was collected twice, at the first top dressing of PU and deep placement of USG and at the second top dressing of PU. At both times, water sampling was done before irrigation and two hours after irrigation followed by next seven days sampling maintaining a specific time of the day to analyze the field water properties like pH, electrical conductivity (EC) and NH_4-N. For determination of NH_4-N, 25 ml water sample was added into a 50 ml volumetric flask and then 2.0 ml phenol solution, 2.0 ml Na-niroprusside and 5.0 ml oxidizing solutions were added and mixed thoroughly. After each addition of reagents the solution was shaken for five minutes to mix well. Then the sample was left for 1 hour for color development after which the absorbance was measured at 640 nm by a spectrophotometer.

Data collection on rice

The rice crop was harvested at maturity and plant height, effective tillers per hill, panicle length, filled grains per panicle and 1000-grain weight were recorded. From each plot ten hills were randomly selected to keep records on yield and yield contributing characters. The selected hills were collected before the crop was harvested and necessary information was recorded accordingly. Grain yield was recorded at 14% moisture basis and straw yield at sun dry basis.

Chemical analyses of soil samples

Soil samples were collected at a depth of 0-15 cm from the surface. After removing weeds, plant roots, stubbles, and stones, the samples were air dried and ground to pass through a 2 mm (10 meshes) sieve. The samples were then stored in clean plastic bags until further chemical and mechanical analyses. Initial soil samples were analyzed for physical and chemical properties following standard methods. Particle size analysis of soil was done by hydrometer method (Black, 1965) and the textural class was determined according to the USDA system. Organic matter was determined by Walkley and Black method (Walkley and Black,1934), soil pH (1:2.5 soil-water) by glass electrode pH meter method (Michael, 1965), total N by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982), available P by Olsen method (Olsen *et al.*, 1954), exchangeable K by Flame Photometer after extraction with 1N NH_4OA_c at pH 7.0 (Knudsen *et al.*, 1982), available S by extracting soil samples with $CaCl_2$, solution (0.15%) and by measuring turbidity by spectrophotometer (Williams and Steinbergs,1959) method and CEC by sodium saturation method (Chapman, 1965).

Chemical analyses of plant samples

The representative grain and straw samples were dried in an oven at 65°C for about 24 hours before they were ground by a grinding machine. Then the ground samples were passed through a 20-mesh sieve and stored in paper bags and kept in desiccators. The grain and straw samples were analyzed for N, P, K and S. Total N, P, K and S contents of plant were determined after H_2SO_4-H_2O_2 digestion method as described by Lu *et al*. (1999).

Nutrient Uptake, (NUE) Nitrogen use efficiency and apparent nitrogen recovery (ANR)

Nutrient uptake (kg ha^{-1}) = $(Gy \times N_{Gr})/100 + (Sy \times N_{st})/100$

where, Gy = Grain yield (kg ha^{-1}), Sy = Straw yield (kg ha^{-1})

N_{Gr} = N content in grain (%), N_{St} = N content in straw (%)

Nitrogen use efficiency (NUE) = $(Gy_{+N} - Gy_{ON})/FN$;

Where, Gy_{+N} = grain yield in treatment with N application

Gy_{0N} = grain yield in treatment without N application

FN = amount of fertilizer N applied (kg ha^{-1}).

Apparent nitrogenrecovery (ANR, kg ha^{-1}) = $(UN_{+N} - UN_{0N})/FN$;

Where, UN_{+N} is total N uptake (kg ha^{-1}) with grain and straw

UN_{0N} is the N uptake (kg ha^{-1}) in control

FN is amount of fertilizer N applied (kg ha^{-1}).

Statistical Analysis

The analyses of variance (ANOVA) for different crop characters as well as for different nutrient concentrations of the treatments were conducted using IRRI STAT and the mean differences were compared by using Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

3. Results and Discussion

Yield components

Plant height, effective tillers hill-1, panicle length, filled grains panicle-1, and 1000- grain weight of rice was significantly influenced due to application of PU and USG alone or in combination with poultry manure (Table-2). The tallest plant of 78.7 cm was found in T5 (56 kg N ha-1 from USG + 3 t ha-1 poultry manure) and the shortest plant of 60.8 cm was found in control (T1). Statistically similar plant height was found in T4 (82 kg N ha-1 from PU + 3 t ha-1 poultry manure) and T3 (119 kg N ha-1 from USG), and T2 (165 kg N ha-1 from PU) treatments with the value of 70.3 cm, 72.8 cm, and 69.8 cm respectively. The maximum number of effective tillers hill-1 (18.67) was found in T5 which was identical to T3 and the minimum value of 8.37 was obtained in control (T1). The largest panicle (23.85 cm) was found in the treatment T5 which was identical with T2, T4 and T3 with the value of 19.98, 18.96 and 21.66 cm, respectively and the smallest panicle (16.93 cm) was observed in T1 (control). Similar observations were made by Reddy et al. (2004) who observed that application of poultry manure (9 tha-1) produced better growth components viz., plant height, number of tillers hill-1, total dry matter per plant and yield components like number of panicle hill-1 and panicle length. The number of filled grains panicle-1 varied from 59.55 to 78.04. The highest value was found in T5 and the lowest value was found in T1 treatment. The treatments T4 and T2 were identical in producing filled grains panicle-1 with the value of 63.26 and 61.85, respectively. The range of 1000-grain weight of rice was 10.63 g to 16.77 g. The highest 1000-grain weight of 16.77 g was found in T5 and the lowest value was noted in T1 treatment. Vennila et al.

(2007) reported that 75% recommended dose of N fertilizer + 25% N as poultry manure increased growth, yield attributes and yield, and nutrient uptake of rice.

Table-2. Effects of integrated use of prilled urea, urea super granule and poultry manure on the yield and yield components of BR 21 rice

Treatment	Plant height (cm)	Effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	1000-grain weight (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})
T_1	60.8d	8.37c	16.93d	59.55d	10.63c	1.99c	3.28c
T_2	69.8bc	15.53b	18.96c	61.85c	14.17b	2.41b	3.79b
T_3	72.8b	18.47a	21.66b	72.35b	15.72a	2.90ab	4.27ab
T_4	70.3bc	15.07b	19.98bc	63.26c	13.39b	2.66b	4.07b
T_5	78.7a	18.67a	23.85a	78.04a	16.77a	3.19a	4.51a
CV (%)	4.87	4.68	6.04	3.31	5.42	6.35	4.92

T_1: Control, T_2: 165 kg N ha^{-1} from PU, T_3: 119 kg N ha^{-1} from USG, T_4: 82 kg N ha^{-1} from PU + 3 t ha^{-1} poultry manure, T_5: 56 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure. Figures in a column having common letters do not differ significantly at 5% level of significance, CV (%) = Coefficient of variation.

Application of PU, USG and poultry manure alone or in combination showed a positive effect on grain yield of rice (Table-2). It was found that the grain yield ranged from 1.99 to 3.19 tha^{-1}. The highest grain yield of 3.19 tha^{-1} was recorded in T_5 (56 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure) which was similar with T_3 (119 kg N ha^{-1} from USG) and the lowest value of 1.99 tha^{-1} was recorded in T_1 (control). The treatment T_4 (82 kg N ha^{-1} from PU + 3 tha^{-1} poultry manure), T_2 (165 kg N ha^{-1} from PU) and T_3 (119 kg N ha^{-1} from USG) produced identical grain yield of 2.66 tha^{-1}, 2.41 tha^{-1} and 2.90 tha^{-1}, respectively. Urea super granules in association with poultry manure treated plot gave better grain yield than other treatments. This might be due to optimum release of N from deep placed of USG for prolonged period and adequate release of N and other nutrient from poultry manure. The increase in grain yield over control ranged from 21.10 to 60.14% where the highest increase was obtained due to T_5 treatment. The grain yields obtained from different treatments may be ranked in the order of $T_5 > T_3 > T_4 > T_2 > T_1$. These results are in agreement with the findings of Khan *et al.* (2007) who reported that grain yield was significantly increased due to application of organic manure and chemical fertilizers. The straw yield of BR 21 rice was also influenced significantly due to the application of PU, USG and poultry manure alone or in combination as shown in Table-2. The straw yield obtained from different treatments ranged from 3.28 to 4.51 tha^{-1}. The highest straw yield of 4.51 tha^{-1} was obtained in T_5 which was similar with T_3 (4.27 tha^{-1}) and the lowest value of 3.28 tha^{-1} was noted in T_1 (control). Uddin et al., 2002 and Rahman *et. al.* (2009) reported that the application of urea-N in combination with cowdung and poultry manure increased the straw yields of rice. The treatments may be ranked in the order of $T_5 > T_3 > T_4 > T_2 > T_1$ in terms of straw yield. These results support the findings of Azad and Leharia (2002) who reported that application of poultry manure in combination with different NPK levels exhibited a significant increase in effective tillers per hill and grain and straw yields over NPK, a significant increase in growth and yield and straw.

Nitrogen uptake

The N uptake both by grain and straw of rice increased significantly due to application of prilled urea, USG and poultry manure alone or in combination. The total N uptake ranged from 34.41 to 64.12 kg ha^{-1}.The highest N uptake by grain (34.80 kg ha^{-1}) and straw (29.32 kg ha^{-1}) was obtained in USG in combination with poultry manure and the lowest N uptake take by grain (18.51 kg ha^{-1}) and straw (15.9 kg ha^{-1}) was found in control (Table-3).

Table-3. Effects of integrated use of prilled urea, urea super granule and poultry manure on nitrogen content and uptake by grain and straw rice

Treatment	N content (%)		N uptake (kgha^{-1})	
	Grain	Straw	Grain	Straw
T_1	1.04c	0.48c	18.51c	15.9d
T_2	1.10bc	0.58b	26.51b	20.82c
T_3	1.15b	0.61b	29.24b	25.26ab
T_4	1.13bc	0.60b	26.37b	24.42bc
T_5	1.19a	0.65a	34.80a	29.32a
CV%	6.45	7.18	12.3	7.24

T_1: Control, T_2: 165 kg N ha^{-1} from PU, T_3: 119 kg N ha^{-1} from USG, T_4: 82 kg N ha^{-1} from PU + 3 t ha^{-1} poultry manure, T_5: 56 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure. Figures in a column having common letters do not differ significantly at 5% level of significance. CV (%) = Coefficient of variation.

The apparent N recovery indicates the absorption efficiency of applied N. Mean apparent recovery of N by rice ranged from 7.22% to 38.92%. Nitrogen use efficiency represents the response of rice plant in terms of grain yield to N fertilizer

(Table-4). The range of nitrogen use efficiency (NUE) varied from 2.54 to 16.17. The highest value of NUE was obtained in T_5 and the lowest value was found in T_2 treatment. Yaqub *et al.* (2010) showed that averaged across urea-N treatments, manuring significantly increased grain N content (4% increase) and grain N uptake (9% increases).

Table-4. Effects of integrated use of prilled urea, urea super granule and poultry manure on apparent N recovery (%) and nitrogen use efficiency (NUE) of rice

Treatments	N applied (kg ha^{-1})	Grain yield (t ha^{-1})	Total N uptake (kg ha^{-1})	ANR (%)	NUE (Kg / kg)
T_1	-	1.99 c	34.41d	-	-
T_2	165	2.41b	47.33c	7.22	2.54
T_3	119	2.90ab	54.5b	16.04	7.64
T_4	100	2.66b	50.79b	15.38	6.70
T_5	74	3.189a	64.21a	38.92	16.17
CV%	-	6.35	9.54	-	-

T_1: Control, T_2: 165 kg N ha^{-1} from PU, T_3: 119 kg N ha^{-1} from USG, T_4: 82 kg N ha^{-1} from PU + 3 t ha^{-1} poultry manure, T_5: 56 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure. Figures in a column having common letters do not differ significantly at 5% level of significance. CV (%) = Coefficient of variation.

Table-5. Effects of integrated use of prilled urea, urea super granule and poultry manure on PKS uptake of rice

Treatment	Uptake(kg ha^{-1})		
	P	K	S
T_1	9.81c	64.67c	11.66d
T_2	11.84b	77.44b	13.79c
T_3	14.23ab	84.44a	17.45a
T_4	14.54a	85.43a	17.26bc
T_5	14.66a	89.42a	19.26b
CV%	16.31	16.31	16.48

T_1: Control, T_2: 165 kg N ha^{-1} from PU, T_3: 119 kg N ha^{-1} from USG, T_4: 82 kg N ha^{-1} from PU + 3 t ha^{-1} poultry manure, T_5: 56 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure.Figures in a column having common letters do not differ significantly at 5% level of significance. CV (%) = Coefficient of variation.

Lin. *et al.* (2009) concluded that application of mixed mineral-fertilizer-N and organic-fertilizers-N had a better effects on N use efficiency could be significantly increased compared with the single application of mineral nitrogen fertilizer. Sengar *et al*. (2000) stated that application of N fertilizer and manures significantly increased the N, P, K uptake by rice.

Field water quality

In first sampling, the amount of available NH_4-N in rice field water started to increase after 2 hours of application, continued up to 3 days and then decreased gradually. The maximum amount of NH_4-N was found at 2^{nd} day after application for all the treatments except control and the treatment T_2 (165 kg N ha^{-1} from PU) produced the highest value of 5.086 ppm or 2.03 kg ha^{-1} followed by T_4 (82 kg N ha^{-1} from PU + 3 tha^{-1} poultry manure) and T_5 (56 kg N ha^{-1} from USG + 3 tha^{-1} poultry manure) which is illustrated in Figure-1. In comparison with PU, the USG application generated available NH_4-N slowly rather spontaneously over the time indicating a beneficial role of USG. In second sampling, the amount of available NH_4-N followed the similar trend of first sampling. However, the increase in the NH_4-N continued up to 4 days of PU application starting from 2 hours. The highest value of NH_4-N (0.46 ppm or 0.32 $kgha^{-1}$) was observed in T_2 at 2^{nd} day after application and that (0.217 ppm or 0.127 $kgha^{-1}$) in T_4 at 4^{th} day after application of urea fertilizer (Figure-2). The application of USG (T_3 and T_5) produced lower amount of NH_4-N compared to PU in second sampling as USG was not applied this time. However, the availability of NH_4-N was spontaneous. The pH of rice field water increased after application of PU and deep placement of USG alone or in combination with poultry manure. In first sampling, all the treatments showed an increase of pH values over control. The pH ranged from 6.4 to 8.15 (Figure-3). The highest pH was found in T_4 at third day after urea application and the lowest pH was observed in T_1 (control). In second sampling, the pH of rice field water was also increased after top dressing of PU.

The treatments T_2 and T_4 showed an increase in pH values over control. The pH ranged from 6.04 to

7.93. The highest pH was found in T_2 at third day after PU application and then reduced gradually. The lowest pH was observed in T_1 (control). The electrical conductivity (EC) of rice field water increased after application of PU and deep placement of USG alone or in combination with poultry manure in both first and second sampling but started to decrease after 5 days and maintained almost a static condition as graphically shown in. During first sampling, EC of rice field water ranged from 95.4 to 305.6 µS cm^{-1} and in second sampling the EC values varied from 48 to 222.3 µS cm^{-1}. The maximum EC value was observed in T_2 (165 kg N ha^{-1} from PU) at fifth day after urea application and then reduced gradually in case of first sampling and in second sampling the EC value reached maximum at 3^{rd} day after urea application (Figure-4).

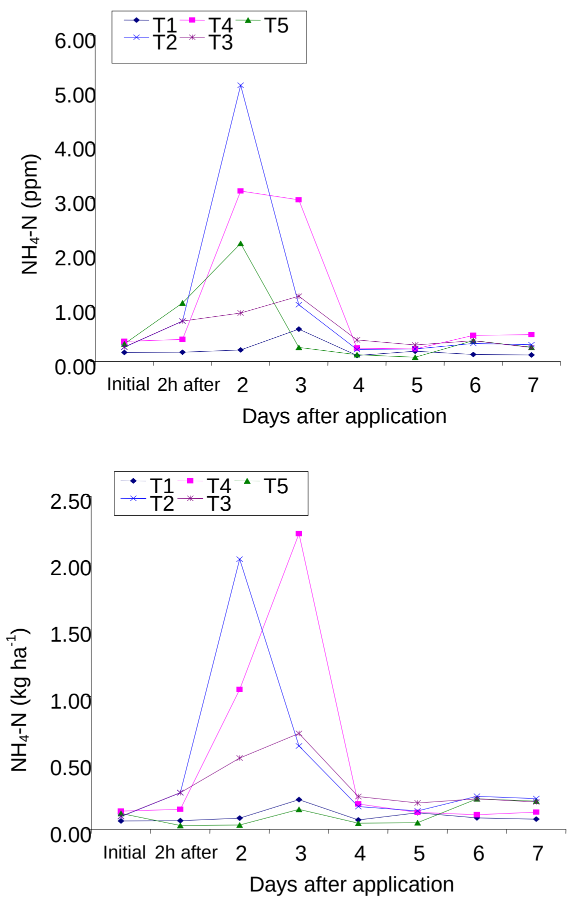


Figure-1. Trends of ammonium concentration in rice field water after application of urea and USG; a) first sampling, and b) second sampling

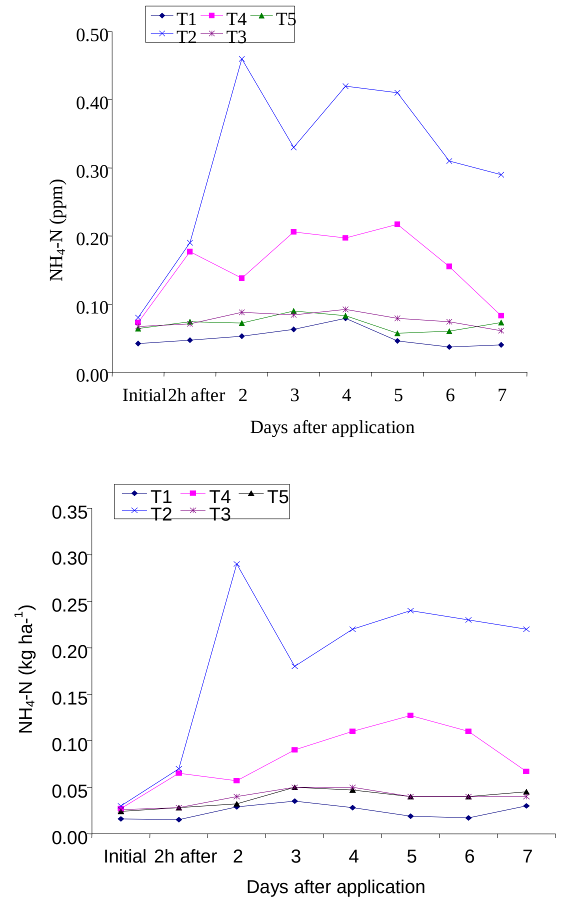
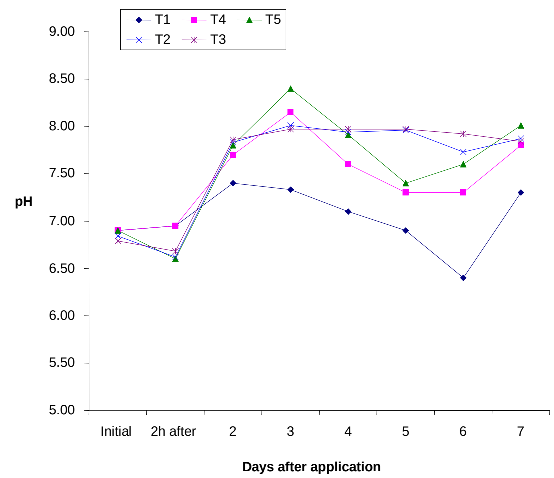


Figure-2. Trends of ammonium concentration in field water after application of urea; a) first sampling, and b) second sampling



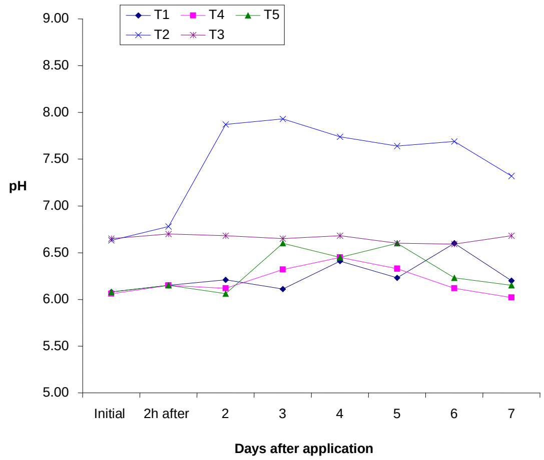


Figure-3. pH trends in rice field water after application of urea ; a) first sampling sampling, and b) second sampling

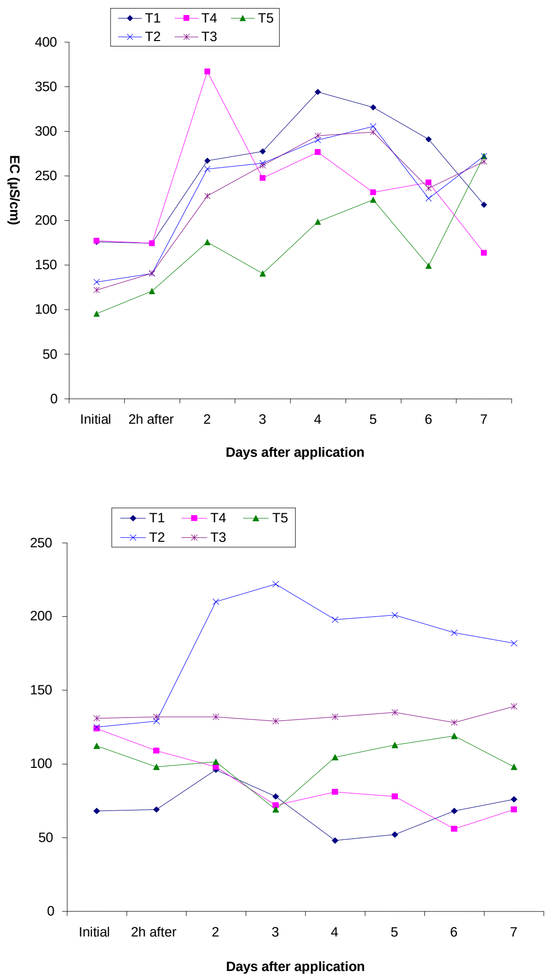


Figure-4. Trends of electrical conductivity of field water after application urea; a) first sampling, and b) second sampling

4. Conclusion

The overall results clearly indicate that the maximum values of grain and straw yield, total N uptake and apparent N recovery were obtained with the application of USG in combination with poultry manure. The reasons for high recovery of applied N could be the deep placement of USG and poultry manure in rice field that resulted in continuous supply of available nitrogen throughout the growth period of rice plant, which ultimately gave maximum N uptake. Deep placement of USG increased nitrogen use efficiency by keeping most of the urea nitrogen in the soil, close to plant roots and out of the irrigation water.

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