Effect of nitrogen fertilizers applied through nano clay polymer composites on nitrogen use efficiency of rice

ABSTRACT

Nitrogen (N) is an essential nutrient for crop growth. However, excessive nitrogen fertilizer application leads to environmental losses.In this study, an attempt was made to reduce the nitrogen losses by loading of urea and urea ammonium nitrate (UAN) into Nano clay polymer composites (NCPCs) to act as slow release N fertilizers. To achieve the objectives of the present study, five N fertilizer treatments (T1-control, T2- N applied through urea, T3-N applied throughUAN, T4-N applied throughNCPC loaded with urea and T5-N applied throughNCPC loaded with UAN) were assessed using three rice genotypes namely IR-64, Nagina 22 and MTU 1010. Results of the greenhouse study indicated that the UAN loaded NCPC treatment was more effective in terms of increasing the grain yield, nitrogen uptake, agronomic use efficiency and apparent nitrogen recovery by 36.9%, 51.0%, 64.2%, and 92.0% over urea, respectively. Amongst the genotypes, MTU 1010 was recorded with highest gran yield followed byIR-64 and Nagina-22.

Key words:*Rice, Genotypes,Nitrogen use efficiency, Nano clay polymer composites, Urea ammonium nitrate*

1. INTRODUCTION

Nitrogen (N) is one of the major essential plant nutrients required for crop growth and development. It's animportant constituent for the nucleotides, amino acids, proteins and chlorophyll and play a major role in cell structure and energy metabolism [1, 2].In order to meet the global food production, 50% of human population relies on nitrogen fertilizers [3]. The excess use of nitrogen fertilizer in agriculture has led to degradation of environment and atmosphere.Rice (*Oryza sativa* L.) is an important staple food crop and increasing its productivity necessitates use of excessive fertilizer N in large quantities asit is the important nutrient element required for their growth [4]. The effect of heavy nitrogen fertilization results in lower nitrogen use efficiency due to the quick N losses in various ways *viz.*, denitrification, ammonia volatilization, leachingand surface runoff in the soil-floodwater system [5]. In India, the major N fertilizer used isurea and it contributes 80% to the total consumption. Urea contributes fifty-five percent of the world total fertilizer consumption. Estimate results that by 2050 about 250 million tons of fertilizer nitrogen may be necessary

[6]. But N use efficiency of urea is very low due to rapid hydrolysis followed by nitrification-denitrification activities, more than 60% of N is lost to the environment [7].

In this direction several slow and controlled release fertilizers have been developed and tested for enhancing N use efficiency. Nano clay polymer composite (NCPC) based N fertilizers are one of the possible option to minimize the N losses and enhancing N use efficiency. As compared to urea, NCPCs loaded with N fertilizers have shown promising results *i.e.*, higher crop yields, enhancing N use efficiency and reduced nitrous oxide emissions in rice- wheat cropping system[8, 9].As rice is a heavy feeder of N, selection of N efficient genotypes is also needed to improve productivity and N use efficiency. In this regard, ongoing efforts are necessary to achieve the highest yields possible with the provision of ideal nitrogen complementing the compromised yield with additional environmental and economic benefits [10].In present studyattempt has been made to study the effect of NCPC based slow release N fertilizers for enhancing N use efficiency under three elite rice genotypes. The study recognizes the benefits of using nano clay polymer composites in enhancing N use efficiency and highlightsN efficient genotype of rice.

2. MATERIALS AND METHODS

2.1 Location and collection of soil sample

Bulk soil sample (Typic Haplustepts) was collected from Main Block 4B experimental farm, Division of Plant Physiology ICAR-IARI, New Delhi. The sample after collection was air dried, ground, sieved to pass through 2mm sieve and used for greenhouse studies.

2.2 Synthesis of nanoclay polymer composite (NCPCs) fertilizers

NCPCs were synthesized by copolymerization reaction of acrylic acid and acrylamide with partial neutralization with ammonia. During the synthesis, bentonite (10% by weight) was added to provide mechanical strength to the polymer, N,Ńmethylenebis acryamide as crosslinker and ammonium persulphate (APS) as free radical initiator [11].

For loading of polymers with N, the known amount of aqueous solution of urea and urea ammonium nitrate was prepared in distilled water separately. The pre-weighted dry ground gels were immersed into the solution to reach swelling equilibrium. Thereafter the swollen gels were dried at 60 °C until constant weight is reached and used for further analysis and application [9].

2.3 Details of greenhouse experiment

The greenhouse experiment was conducted using rice as a test crop at NanajiDeshmukh Plant Phenomics Centre, IARI, New Delhi during kharif season of the year 2018. Stated below are five treatments:

T1: Control (with no nitrogen),

T2: 100% RDF-N in the form of urea,

T3: 100% RDF-N N in the form of UAN,

T4: 100% RDF-N - N in the form of urea loaded in NCPCs,

T5: 100% RDF-N N in the form of UAN loaded in NCPCs)

All treatments were replicated three timeswith three rice genotypes (IR-64, Nagina 22 and MTU 1010) in a Factorial Completely Randomized Design.The fertilization was given to after 40 DAT with full dose of phosphorus in the form of SSP and potassium in the form of murate of potash as per the recommended dose of fertilizer (RDF-120:80:60 Kg/ ha). Nitrogen fertilization was given at three splits with 33% of the recommended dose in each split (basal, maximum tillering and anthesis stage) with the respective sources.

2.4 Soil and plant analysis

Soils were sampled after harvest. Soils were thoroughly mixed, extracted with KCl (2M) and then analyzed for mineral nitrogen content (NH_4 and NO_3-N) [12].After recording the dried biomass of crop, plant sample were ground and nitrogen concentrations in grain and straw samples were determined using Kjeldhal digestion and distillation method [13]. Nitrogen uptake in straw and grain was estimated by multiplying the concentration of N with corresponding grain and straw biomass respectively. The summation of N uptake in grain and straw gives the total uptake in plant. Various yield attributes like nitrogen content in plants, apparent nitrogen recovery, agronomic use efficiency and physiological use efficiency were recorded after the harvest of the crop.

2.5 Statistical analysis

All treatments were subjected to the two-way analysis of variance (ANOVA) based on the experimental design (two factor completely randomized design) as given by Gomez and Gomez [14].

3. RESULTS

3.1 Grain yield of rice

The highest grain yield was recorded under NCPC loaded UAN (29.3 g/pot) followed by NCPC loaded with urea (25.7 g/pot) whereas; urea and UAN treatments were statistically at par with each other in terms of grain yield (Table 1). In case of genotypes, MTU 1010 recorded significantly higher grain yield (26.3 g/pot) followed by IR 64 (24.0 g/pot) and Nagina 22 (13.7 g/pot).The interaction betweenrice genotype and N treatments showed statistically significant differences when MTU1010 treated with NCPC loaded with UAN resulted in highest grain yield (35.4 g/pot) over other interaction combinations.

Table 1: Effect of N sources on the grain yield (g/ pot) of three rice genotypes

Sources of Nitrogen (Treatments)	Rice genotypes (G)			
	IR-64	Nagina 22	MTU1010	Mean
Control	10.0	5.84	10.5	8.79
100% Urea	25.3	12.4	26.5	21.4
100% UAN	24.2	13.3	27.0	21.5
100% NCPC loaded Urea	27.8	17.1	32.0	25.7
100% NCPC loaded UAN	32.8	19.8	35.4	29.3
Mean	24.0	13.7	26.3	
CD (5%)	G= 1.53 T= 2.00 G*T=3.47			
SEm (±)	G= 0.51 T= 0.659 G*T=1.14			

3.2 Straw yield of rice

The straw yield of different rice genotypes studied under varied N-treatments showed significant differences. The NCPC loaded with UAN resulted in the highest straw biomass (45.5 g/pot) followed by NCPC loaded with urea (38.6 g/pot). The treatment of urea and UAN performed statistically at par with each other for straw biomass (Table 2). All genotypes of rice showed statistically significant differences for straw biomass where IR 64 has the highest straw biomass (37.1 g/pot) followed by MTU 1010 and Nagina 22. The interaction between rice genotype and N treatment was non-significant.

Table 2: Effect of N sources on straw yield (g/ pot) of three rice genotypes

Sources of Nitrogen (Treatments)	Rice genotypes (G)			
	IR-64	Nagina 22	MTU1010	Mean
Control	18.0	10.8	11.9	13.6
100% Urea	33.7	26.5	29.6	29.9
100% UAN	39.9	26.2	31.1	32.4
100% NCPC loaded Urea	43.9	33.3	38.7	38.6
100% NCPC loaded UAN	50.2	41.0	45.3	45.5
Mean	37.1	27.6	31.3	
CD (5%)	G= 2.98 T= 3.85 G*T=NS			
SEm (±)	G= 0.98 T= 1.27 G*T=2.19			

3.3 Total nitrogen uptake in rice grain and straw

The NCPC loaded with UAN gave significant highest uptake (0.74 g/pot) of nitrogen over rest of the fertilizer treatments. The urea and UAN treatments were statistically at par with each other in respect of nitrogen uptake by rice and both these treatments were statistically inferior to the NCPC loaded with urea (0.62 g/pot).Both genotypes, IR64 and MTU1010 recorded significantly higher nitrogen uptake over Nagina 22 (Table 3).No significant differences in interactions were observed between genotype and fertilizer treatments.The total nitrogen uptake of MTU 1010 was statistically similar with IR 64 in having the highest nitrogen uptake as these two genotypes produced more or less similar straw and grain yield as compared to Nagina 22.

Table 3: Effect of N sources on the total uptake of N (g/pot) of three rice genotypes at harvest

Sources of Nitrogen (Treatments)	Rice genotypes (G)			
	IR-64	Nagina 22	MTU1010	Mean
Control	0.23	0.13	0.19	0.18
100% Urea	0.55	0.36	0.55	0.49
100% UAN	0.57	0.37	0.57	0.50
100% NCPC loaded Urea	0.67	0.49	0.70	0.62
100% NCPC loaded UAN	0.81	0.60	0.82	0.74
Mean	0.56	0.39	0.57	
CD (5%)	G= 0.03 T= 0.04 G*T=NS			
SEm (±)	G= 0.01 T= 0.01 G*T=0.02			

3.4 Apparent nitrogen recovery

Apparent N recovery (ANR) increased with the increase in the uptake of nitrogen from soil compared to control. Highest ANR (53.2%) was found with NCPC loaded UAN treatment and lowest (27.7%) was obtained in urea treatment, statistically similar with UAN treatment (29.3%). Both urea and UAN treatments were statistically inferior to NCPC loaded treatments in terms of ANR. Among the genotypes, both IR 64 (42.4%) and MTU 1010 (42.2%) gave similar ANR and these were significantly higher over Nagina 22(Table 4).The highly responsive MTU1010 genotype being highest yielder absorbed highest N when treatedwith NCPC loaded with UAN (T4) because T4 has ability to supply more nitrogen at required rates for longer time.Interaction effect between genotype and treatment combinations was non-significant.

Table 4: Effect of N sources on the apparent nitrogen recovery (%) of three rice genotypes

Sources of Nitrogen (Treatments)	Rice genotypes (G)			
	IR-64	Nagina 22	MTU1010	Mean
100% Urea	32.5	19.4	31.3	27.7

100% UAN	33.9	20.6	33.3	29.3
100% NCPC loaded Urea	44.7	31.9	46.2	41.0
100% NCPC loaded UAN	58.6	43.1	57.8	53.2
Mean	42.4	28.8	42.2	
CD (5%)	G= 4.85 T= 5.60 G*T=NS			
SEm (±)	G= 1.56 T= 1.80 G*T=3.12			

3.5 Agronomic use efficiency

Agronomic use efficiency (AUE) is the increase in yield per unit nitrogen applied along with NCPC over urea and UAN treatments. The data (Table 5)showed significant differences among the treatments applied to three rice genotypes. Highest AUE (20.2 g/g N) was found with NCPC loaded UAN treatment a lowest in (12.3 g/g N) in urea which was statistically similar to UAN treatment. In case of different genotypes, MTU 1010 showed the significant highest AUE (18.8 g/g N)indicating its highly responsive nature for the applied nitrogen sources, which was statistically similar to IR 64 (17.5 g/g N) and both these genotypes were statistically superior over Nagina 22 (9.8 g/g N). There were no significant differences observed among the various interactions of genotype and treatment combinations.

Table 5: Effect of N sources on the agronomic use efficiency (g/g N) of three rice genotypes

Sources of nitrogen (Treatments)	Rice genotypes (G)			
	IR-64	Nagina 22	MTU1010	Mean
100% Urea	15.2	6.60	15.1	12.3
100% UAN	14.2	7.50	15.6	12.4
100% NCPC loaded Urea	17.8	11.3	20.6	16.6
100% NCPC loaded UAN	22.7	14.0	24.0	20.2
Mean	17.5	9.80	18.8	
CD (5%)	G= 2.53 T= 2.92 G*T=NS			
SEm (±)	G= 0.81 T= 0.94 G*T=1.63			

3.6 Physiological use efficiency

The physiological use efficiency (PUE) increases with increase in the difference of yield between treated and control pots and decrease in the difference of uptake of nitrogen between treated and control pots (Table 6). PUE in this study ranged from 37.5 to 42.9 g/g N under various treatment applications. The maximum PUE (42.9 g/g N) was observed with urea and minimum (37.5 g/g N) in NCPC loaded UAN treatment. The highest being for urea treated pots signifying some losses occurred in the soil and thus resulting in low uptake and thus giving highest physiological use efficient treatment. In case of different genotypes, highest PUE (45.2 g/g N) was obtained with MTU 1010 and which was statistically at par with IR 64.

Table 6: Effect of N sources on the physiological use efficiency of three rice genotypes

Sources of Nitrogen (Treatments)	Rice genotypes (G)			
	IR-64	Nagina 22	MTU1010	Mean
100% Urea	46.9	34.1	47.8	42.9
100% UAN	41.9	36.3	46.9	41.7
100% NCPC loaded Urea	39.8	35.4	44.6	39.9
100% NCPC loaded UAN	38.8	32.4	41.4	37.5
Mean	41.8	34.6	45.2	
CD (5%)	G= 3.63 T= NS G*T=NS			
SEm (±)	G= 1.17 T= 1.35 G*T=2.33			

3.7 Soil mineral nitrogen

The mineralnitrogen content in soil was determined immediately after the harvest of rice crop. The treatment of NCPC loaded with UAN showed significantly higher amount of mineral nitrogen content (55.2 mg/kg) followed by NCPC loaded with urea, urea, UAN, and control treatments (Table 7). The NCPC might have retained and regulated both ammonical as well as nitrate nitrogenand released slowly to rice crop. The genotype Nagina 22 retained significant highest amount of mineral nitrogen content (50.1 mg/kg) in the soil followed by IR64 and MTU1010. To quote about the interaction effect, there were no significant differences.

Table7: Effect of N sources on the soil mineral nitrogen (mg/kg) of three rice genotypes at harvest

Sources of nitrogen (Treatments)	Rice genotypes (G)			
	IR-64	Nagina 22	MTU1010	Mean
Control	34.0	39.7	32.7	35.5
100% Urea	45.6	49.7	41.2	45.5
100% UAN	43.8	46.3	41.8	44.0
100% NCPC loaded Urea	51.2	55.9	47.0	51.3
100% NCPC loaded UAN	56.3	59.0	50.3	55.2
Mean	46.2	50.1	42.6	
CD (5%)	G= 1.30 T= 1.68 G*T=NS			
SEm (±)	G= 0.43 T= 0.55 G*T=0.96			

4. DISCUSSION

4.1 Plant growth and Nitrogen use efficiency

Maximum plant biomass (grain + straw) was recorded under NCPC treated soils which resulted in to higher N uptake and use efficiencies. It might be due to synchronized release of

N from the NCPC based N fertilizers, so that the plants get more opportunity to absorb nitrogen and subsequently increase in production [15].Shoji [16]also synthesized different controlled release N fertilizers and confirmed the enhancement of crop yield and NUE. Among genotypes, IR 64 gave the highest straw yield followed by MTU 1010 when treated with NCPC loaded with UAN. The delayed panicle initiation of the genotype IR 64 having more time for its vegetative growth resulting in the second highest number of tillers next to MTU 1010 might be the reason for having highest straw yield at harvest, as the panicle and effective tillers are a major indicators of production per plant [4].

Kaneta *et al*. [17] found that the N uptake was notably increased by the use of polyolefin-coated urea which can release N in a pattern that matches the N demand of the rice during the whole growing season. Similarly, Zhao *et al*., [18] studied the effect of fertilizer loaded nano clay polymer composites on the chlorophyll content in maize crop and observed the enhanced photosynthetic rate after anthesis in maize. Nutrient uptake is the product of nutrient concentration and yield, hence, uptake generally follows the yield trend.The increase in N uptake is due to better availability and absorption of N in balanced quantity because of good proliferation of root system [19].

4.2 Mineral nitrogen availability

At the same level of N fertilizer application, ammonical N content was significantly higher under NCPC treatments compared to conventional fertilizer. This indicated that NCPC could maintain a gradual release of loaded nutrients in soil for longer period. On the other hand, rapid hydrolysis of urea under conventional fertilizer and subsequent nitrification – denitrification resulted in losses of N from the soil system [20, 21]. Total mineral N content was also recorded under NCPC treated soils as under rice crop major portion of mineral N remain in ammonical form due to reduced conditions. Jatav *et al.*, [22] also reported an increase in total mineral nitrogen in soils on application of fertilizer loaded NCPCs over conventional fertilizer due to slow release pattern of N from the NCPC based fertilizers.

5. CONCLUSION

Study data indicates that T5 (NCPC loaded with UAN) treatment gave significantly higher results for various yield and yield attributes followed by T4 (NCPC loaded with Urea). Among genotypes, MTU 1010 recorded highest yields and responded well to the nitrogen sources, irrespective of treatments. Meanwhile, Nagina 22 was a least N responsive genotype. Study found, increase in grain yield and NUE from nano clay polymer composite (NCPC) treated fertilizers because N supply from NCPCs closely matched the N needs of the crops.Further research has to be conducted on the usage of NCPC fertilizers at graded doses under field conditions.

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