

Effect of nitrogen applied through nano clay polymer composites on nitrogen use efficiency of three elite rice genotypes

ABSTRACT

Nitrogen (N) is a crucial nutrient for crop growth, and its efficient utilization is imperative for global food production. 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 through UAN, T4-N applied through NCPC loaded with urea and T5-N applied through NCPC loaded with UAN) were assessed using three elite rice genotypes namely IR-64, Nagina 22 and MTU 1010. Results of the greenhouse study indicated that the treatment NCPC loaded with UAN was more effective in 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 responded efficiently in having highest percentage grain yield by 9.58 and 91.97 over IR-64 and Nagina-22 respectively.

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

1. INTRODUCTION

Nitrogen (N) is one of the major essential plant nutrients required for crop growth and development. It's an important 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 as it 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, leaching and surface runoff in the soil-floodwater system [5]. In India, the major N fertilizer used is urea 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 [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 study attempt 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 highlights N efficient variety of rice.

2. MATERIALS AND METHODS

2.1 Location and collection of soil sample

To accomplish the objectives of present study, bulk soil sample (Typic Haplusteps) was collected from Main Block 4B experimental farm, Division of Plant Physiology ICAR-IARI, New Delhi following standard protocol. The sample after collection was air dried, ground, sieved to pass through 2mm sieve and used for green house 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,N'-methylenebisacryamide 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.

2.3 Greenhouse experiment

The green house experiment was conducted using rice as a test crop at NanajiDeshmukh Plant Phenomics Centre, IARI, New Delhi during kharif 2018. Total five N 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) in combination with three rice varieties (IR-64, Nagina 22 and MTU 1010) were replicated three times in a factorial completely randomized design. Transplanting of rice seedlings was done along with application of full dose of phosphorus and potassium and one third dose of N with respective sources. Remaining N was applied in two splits at 40 and 60 days after transplanting (DAT).

2.4 Soil and plant analysis

Soils were sampled after harvest. Soils were thoroughly mixed, extracted with KCl (2N) and then analyzed for mineral nitrogen content (NH_4 and $\text{NO}_3\text{-N}$) [12]. After recording the dried biomass of crop, plant samples 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 treatment and variety combinations were subjected to the two-way analysis of variance (ANOVA) appropriate to the experimental design (two factor completely randomized design) as given by Gomez and Gomez [14].

3. RESULTS

3.1 Grain yield

The significant 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 varieties, 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 effect of variety and 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 elite rice genotypes

Sources of Nitrogen (Treatments)	Rice Varieties (V)			
	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%)	V= 1.53 T= 2.00 V*T=3.47			
SEm (\pm)	V= 0.51 T= 0.659 V*T=1.14			

3.2 Straw yield

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 was non-significant.

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

Sources of Nitrogen (Treatments)	Rice Varieties (V)			
	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%)	V= 2.98 T= 3.85 V*T=NS			
SEm (\pm)	V= 0.98 T= 1.27 V*T=2.19			

3.3 Uptake of nitrogen

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 varieties, IR64 and MTU1010 recorded significantly higher nitrogen uptake over Nagina 22 (table 3). No significant differences in interactions were observed between variety 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 elite rice genotypes at harvest

Sources of Nitrogen (Treatments)	Rice Varieties (V)			
	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%)	V= 0.03 T= 0.04 V*T=NS			
SEm (±)	V= 0.01 T= 0.01 V*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 varieties, 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 took up more nitrogen when treated with NCPC loaded with UAN because of its ability to supply more nitrogen at required rates for long time. Interaction effect was non-significant between variety and treatment combinations.

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

Sources of Nitrogen (Treatments)	Rice Varieties (V)			
	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%)	V= 4.85 T= 5.60 V*T=NS			

SEm (\pm)	V= 1.56	T= 1.80	V*T=3.12
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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 (table 5). The data 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 varieties were statistically superior over Nagina 22 (9.8 g/g N). There were no significant differences observed among the various interactions of variety and treatment combinations.

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

Sources of nitrogen (Treatments)	Rice Varieties (V)			
	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%)	V= 2.53 T= 2.92 V*T=NS			
SEm (\pm)	V= 0.81 T= 0.94 V*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 elite rice genotypes

Sources of Nitrogen (Treatments)	Rice Varieties (V)			
	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%)	V= 3.63 T= NS V*T=NS			
SEm (\pm)	V= 1.17 T= 1.35 V*T=2.33			

3.7 Soil mineral nitrogen

The mineral nitrogen content in soil was determined 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 nitrogen forms of ammonium as well as nitrate and 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 elite rice genotypes at harvest

Sources of nitrogen (Treatments)	Rice Varieties (V)			
	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%)	V= 1.30 T= 1.68 V*T=NS			
SEm (\pm)	V= 0.43 T= 0.55 V*T=0.96			

4. DISCUSSION

4.1 Plant growth and Nitrogen use efficiency

Maximum plant biomass (grain + straw) was recorded under NCPC treated soils both with urea and UAN which ultimately 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 N use efficiencies. Among varieties, IR 64 gave the highest straw yield followed by MTU 1010 when treated with NCPC loaded with UAN. The delayed panicle initiation of the variety 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. Since nutrient uptake is the product of nutrient concentration and yield, hence, uptake generally followed the yield trend. Which ultimately leads to enhanced recovery and agronomic use efficiency of nitrogen. 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 same level of N fertilizer application, ammonium 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

The NCPC loaded UAN treatment gave significantly higher results for various yield and yield attributes followed by NCPC loaded Urea. Among genotypes, MTU 1010 gave highest yields and the same variety responds well to the nitrogen source irrespective of any fertilizer treatment. Whereas, Nagina 22 is the tolerant variety irrespective of any nitrogen sources it was not influenced much by the different fertilizer sources. Higher grain yield, N use efficiency and higher N uptake from NCPCs treated fertilizers were obtained in this study because of the N release/supply from NCPCs closely matched the N needs of the crops

which might be due to synchronized supply of N into the soil for plant uptake by NCPC fertilizers. Further research has to be conducted on the usage of NCPC fertilizers at graded doses under field conditions.

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