Original Research Article

Effect of Crop Establishment Methods and Nano Urea Compared to Blank Urea on Quality and Nutrient Uptake in Rice Crop (*Oryza sativa* L.)

ABSTRACT

A field experiment was conducted during *Kharif* season 2022 and 2023 at Agronomy research farm, Acharya Narendra Deva University of Agriculture and Technology Kumarganj, Ayodhya, Uttar Pradesh, (India). The experiment was laid out in split plot design with thrice replications. Taking three crop establishment methods Direct Seeded Rice, System of Rice Intensification (SRI) and Transplanted Rice in main plot and seven nitrogen levels control, 100 % RDN through conventional Urea, 100 % RDN through Nano Urea, 80 % RDN through conventional Urea + 20 % RDN through Nano Urea, 60 % RDN through conventional Urea + 40 % through Nano Urea, 40 % RDN through conventional Urea + 60 % through Nano Urea and 20 % RDN through conventional Urea + 80 % through Nano Urea in sub plot. Results showed that significantly higher NPK content, NPK uptake protein content and protein yield was recorded in application of 60 % RDN through conventional Urea + 40 % through Nano Urea which was at par with 40 % RDN through conventional Urea + 60 % RDN through Nano Urea significantly superior over rest of the treatment during both the years of investigations.

Keywords: Protein content, Protein yield, NPK Uptake, Nano urea, Conventional Urea,

1. INTRODUCTION

"Rice (*Oryza sativa* L.) a member of the Poaceae family, it is said to have come from South-East Asia. In both regions of the temperate region and the tropics, it is one of the most significant cereal crops" of Mohapatra *et al.* (2022). "The cultivated species are *Oryza sativa* and *Oryza glaberrima. Oryza sativa* is grown all over the world while *Oryza glaberrima* has been cultivated in West Africa for the last 3500 years. The production of rice in the world is about 509.26 million metric tons with the productivity of 4.60 metric tons ha-1 having area 165.21 million ha" (FAS/USDA, 2021- 2022). "In India, rice is cultivated in the area of 450.57 Lakh ha with an annual production of 122.27 million tons and average productivity of 2713 kg ha-1" (Anonymous, 2021-22). "It is a high caloric food, which contain 75% starch, 6-7% protein, 2-2.5% fat, 0.8% cellulose and 5-9% ash"[24,25,26].

"The System of Rice Intensification, known by its acronym 'SRI', is gaining popularity among paddy farmers in several states. This method has the potential to improve productivity of land, capital, water and labour simultaneously. Transplanting in puddled soil is the most dominant and traditional method of rice establishment in irrigated low land ecosystem" by Wang *et al.* (2013). Puddling, reduce water infiltration and to maintain the standing water in the field, which also helps in reducing weed density, preventing leaching losses of plant nutrients, increases water retention capacity and facilitates easier transplanting. Direct seeding of rice is one of the methods of rice cultivation, which refers to the process of establishing rice crop from seeds sown in the field rather than transplanting rice (TPR) seedlings from the nursery whereas aerobic rice cultivation is a practice of direct drilling of seeds in rows and maintaining aerobic conditions of the field under limited water availability.

2. MATERIALS AND METHODS

The experiment was conducted during two consecutive seasons of *Kharif* 2022 and 2023 at the Agronomy Research Farm, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) which is situated on Ayodhya-Raebareli Road at the distance of 42 km from Ayodhya district head quarter. The experimental site falls under sub- tropical conditions with remarkable humidity and lies between 24.40 North latitude and 82.12^0 East longitudes with an altitude 113 meters above mean sea level. The experimental field was well leveled having good irrigation and drainage facilities. The source of irrigation was tube well. The experiment was layout in split plot design (SPD) with three replications taking three crop establishment methods direct seeded rice (DSR), System of Rice Intensification (SRI), transplanting rice in main plot and seven nitrogen level N_1:Control, N_2: 100 % RDN through conventional Urea, N_3: 100 % RDN through Nano Urea, N_4: 80 % RDN through conventional Urea + 20 % RDN through Nano Urea, N_5: 60 % RDN through conventional Urea + 40 % through Nano Urea, N_6: 40 % RDN through conventional Urea + 60 % through Nano Urea and N_7: 20 % RDN through conventional Urea + 80 % through Nano Urea in sub plot. Soil was sampled before sowing and after harvest of the crop to know the fertility status of the experiment field.

2.1 Nutrient content in grain and straw:

Nitrogen content in grain and straw was analyzed by modified micro-Kjeldahl method (Jackson, 1973) by digesting samples in sulphuric acid in a micro-Kjeldhal flask (digestion tube) on a hot plate. The distillation process was carried out using Nitrogen Analyzer and titration was carried out using digital burette.

Phosphorus content in grain and straw of rice crop was estimated by Vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973) and the intensity of yellow colour was read with Spectro-photometer at 420 nm and the contents were expressed in terms of percentage phosphorus. Estimation of potassium content in grain and straw by flame emission photometry method (Jackson, 1973) was used in di-acid digested samples and reported as percent potassium.

2.2 Nutrient uptake by grain and straw:

The nitrogen content in plant was determined by Kjeldahl's method (Bremner and Mulvaney, 1982). "The grain and straw were separated and then grinded. The grinded material was digested in concentrated sulphuric acid using copper sulphate and potassium sulphate mixture as catalyst. The digested material was then distilled with 40 per cent sodium hydroxide and distillate was collected in boric acid containing the mixed indicator. The content was estimated by titrating the distillate against N/20 sulphuric acid. The nitrogen uptake was calculated by multiplying the dry weight with nitrogen content. In order to get total uptake of nitrogen, the uptake values for grain and straw were added together". [27]

"The phosphorus uptake was determined in the extract by Vando molybdate yellow color method. The optical density (OD) was measured with photoelectric colorimeter at 470nm. The content was estimated with calibration curve. The phosphorous uptake by grain and straw per hectare was calculated with the help of per cent value of phosphorus and yield of grain and straw. In order to get uptake of phosphorous, the uptake value for grain and straw were added together plot wise". [27]

The potassium content was determined with the help of flame photometer (Jackson, 1973) and was estimated with calibration curve. Total uptake of potassium by rice grain and straw was calculated by multiplying their relative contents with yield and values were added to know the total uptake of potassium in kg/ha.

Grain uptake (kg ha^{-1}) = Grain yield (q ha^{-1}) x Nutrient content (%) in grain

Straw uptake (kg ha^{-1}) = Straw yield (q ha^{-1}) x Nutrient content (%) in straw

2.3 Protein content in grains:

Protein content in grain was estimated by assessing total nitrogen (Kjeldahl's method) and protein content was computed by multiplying the nitrogen content in grain with factor 6.25 (AOAC, 1995).

Protein content (%) = Nitrogen content (%) × 6.25

2.4 Protein yield (Kg/ha):

Protein yield of rice was calculated by multiplying the respective grain yield (kg/ha) with their protein content in grains divided by 100.

3. RESULTS AND DISCUSSION

4.4.1 Nitrogen content in grins (%)

Data indicated that nitrogen content (%) in grain did not have any significant difference among the crop establishment methods during both the years of investigation was presented in Table 1. The highest nitrogen content in grain (1.203 % and 1.217 %) was recorded in SRI method during 2022 and 2023, respectively.

Perusal of the data revealed that nitrogen content (%) in grain differed significantly among the nitrogen levels during both the years of investigations. The highest nitrogen content in grains (1.26 % and 1.28 %) was recorded with application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5), which was at par with application of 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6), treatment during 2022 and 2023, respectively. Minimum nitrogen content in grain (1.16 % and 1.17 %) was recorded under control (N_1) treatment during 2022 and 2023, respectively. The higher nitrogen content was mainly due to higher growth and development. This might be due to compatibility of the levels in atmospheric nitrogen fixation and higher biomass production. This finding was in conformity with that of Singh *et al.* (2013).

4.4.2 Nitrogen content in straw (%)

Data revealed that nitrogen content (%) in straw did not have any significant difference among the crop establishment methods during both the years of investigation. In general, the highest nitrogen content in straw (0.444 % and 0.450 %) was recorded in SRI method during 2022 and 2023, respectively.

Perusal of the data revealed that nitrogen content (%) in straw differed significantly among the nitrogen levels during both the years of investigation. The highest nitrogen content in straw (0.468 % and 0.474 %) was recorded with application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5), which was at par with application of 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6) treatment during 2022 and 2023, respectively. However, Minimum nitrogen content in straw (0.415 % and 0.420 %) was recorded under control (N_1) during both the years, respectively.

4.4.3 Nitrogen uptake by grins (kg ha^{-1})

Data pertaining to as influenced by crop establishment methods and nitrogen levels has been presented in Table 1. It is evident from the data that all the treatments brought significant influenced on the nitrogen uptake by grains during the both years of experimentation.

The grains produced from SRI method (M_2) was recorded with highest amount of nitrogen uptake (66.79 and 72.20 kg ha^{-1}), which was at par with transplanted (M_3) while, significantly superior over the remaining crop establishment methods during both the years of investigation.

Among nitrogen levels, application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5) recorded with highest amount of nitrogen uptake (69.30 and 74.04 kg ha^{-1}), which was at par with 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6) while, significantly superior over rest of the treatments during 2022 and 2023, respectively. However, the lowest nitrogen uptake by grains (42.58 and 46.27 kg ha^{-1}) was recorded under control treatment (N_1) during both years of experimentations. At the later growth stages of rice, the amount of N uptake was recorded an increase which might be due to the greater biomass production of as well as increased absorption. Sreenivas *et al.*, (2000) and Bakhtiar and Sakurai (2005) also reported similarly.

Nutrient uptake is a function of dry matter production and is partly due to increase in nutrient concentration. However, there is a close relationship between the total uptake of nutrients with the grain yield and straw yield of rice crop. The higher nutrient uptake by rice was found to be increased with foliar application of nano urea which might be due to nano fertilizer have large surface area and particle size is less than the pore size of root and leaves of the plant which increase their penetration into the plant from applied surface and improve nutrient uptake. These result findings were in close agreement with the findings of Lahari *et al*. (2021), De Rosa *et al*. (2010), Kumar *et al*. (2014), Jhanzab *et al*. (2015), Adhikari *et al*. (2014), Manikandan and Subramanian, (2016), Khalil *et al.* (2019) and Sahu *et al*. (2022).

4.4.4 Nitrogen uptake by straw (kg ha^{-1})

Data pertaining to nitrogen uptake by straw of rice as influenced by crop establishment methods and nitrogen levels has been presented in Table 1. It is evident from the data that all the treatments brought significant influence on the nitrogen uptake by straw during the both years of investigation.

Crop establishment method showed significant impact on nitrogen uptake by straw during both the years of investigation. The maximum nitrogen uptake in straw (34.84 and 37.50 kg ha^{-1}) was recorded with SRI method (M_2), which was at par with transplanted rice (M_3) while, significantly superior over rest of the treatment during 2022 and 2023, respectively.

Among the nitrogen levels had significant effect on nitrogen uptake by straw during both the years of investigation. Highest amount of nitrogen uptake (35.97 and 38.16 kg ha^{-1}) by straw was found with the application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5), which was at par with 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6) while, significantly higher than rest of the treatments. However, the lowest nitrogen uptake by straw (22.27 and 24.25 kg ha^{-1}) was recorded under control (N_1) treatment. Such increase might be due to the higher grain yield resulting from the greater uptake of nitrogen through application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea. The results of the present investigation are in agreement with the findings of Raut *et al.* 2020.

4.4.6 Phosphorus content in grins (%)

Data pertaining to phosphorus content (%) in grain as influenced by crop establishment methods and nitrogen levels has been presented in Table 2.

Data indicated that phosphorus content (%) in grain did not show any significant effect on crop establishment methods during both the years of investigation. In general, the highest phosphorus content in grain (0.373 % and 0.377 %) was recorded in SRI method during 2022 and 2023, respectively.

Perusal of the data revealed that phosphorus content (%) in grain differed significantly among the nitrogen levels during both the years. The highest phosphorus content in grains (0.377 % and 0.380 %) was recorded with application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5), which was at par with N_6 and N_7 during both the years of investigation. However, Minimum phosphorus content in grain (0.252 % and 0.354 %) was recorded under control (N_1) during both the years, respectively. The higher nitrogen content was mainly due to higher growth and development.

4.4.7 Phosphorus content in straw (%)

Data pertaining to phosphorus content (%) in straw as influenced by crop establishment methods and nitrogen levels has been presented in Table 2.

Data revealed that phosphorus content (%) in straw did not have any significant difference among the crop establishment methods during both the years. In general, the highest phosphorus content in straw (0.099 % and 0.100 %) was recorded in SRI method during 2022 and 2023, respectively.

Perusal of the data revealed that phosphorus content (%) in straw differed significantly among the different nitrogen levels during both the years. The highest phosphorus content in straw (0.105 % and 0.106 %) was recorded with application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5), which was at par with N_6 and N_7 while, significantly superior over rest of the treatment during 2022 and 2023, respectively. However, Minimum phosphorus content in straw (0.094 % and 0.95 %) was recorded under control (N_1) during both the years, respectively. Similar responses were observed by Singh *et al.* (2012).

4.4.8 Phosphorus uptake by grins (kg ha^{-1})

Data pertaining to phosphorus uptake by grains of rice as influenced by crop establishment methods and nitrogen levels has been presented in Table 2. It is evident from the data that crop establishment methods brought significant influence on the phosphorus uptake by grains during the both years of experimentation.

The maximum phosphorus uptake in grains (20.74 and 22.37 kg ha^{-1}) was recorded with SRI method (M_2), which was at par with transplanted rice (M_3) while, significantly superior over rest of the treatments during both the years.

The nitrogen levels had significant effect in respect of phosphorus uptake by grains (kg ha^{-1}) during both the years of investigation. Maximum phosphorus uptake by grains (21.10 and 22.36 kg ha^{-1}) was recorded with application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5), which was at par with 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6) while, significantly superior over rest of the treatment during 2022 and 2023, respectively. However, the minimum phosphorus uptake by grains (12.89 and 13.99 kg ha^{-1}) was recorded under control (N_1) during both years of investigation. Uptake of phosphorus in grain and straw was significantly increased due to increased nitrogen levels. Increase in the uptake of phosphorus had significant impact by the application of nitrogen levels. Higher phosphorus uptake could be attributed to the higher availability of phosphorus in soil. These results were in conformity with the findings of Nishanth and Biswas (2008).

The interaction effect of crop establishment methods of rice and nitrogen levels on potassium uptake in rice grain was found to be non-significant during both the years.

4.4.9 Phosphorus uptake by straw (kg ha^{-1})

Data pertaining to phosphorus uptake by straw of rice as influenced by crop establishment methods and nitrogen levels has been presented in Table 2. It is evident from the data that crop establishment methods brought significant influence on the phosphorus uptake by straw during the both years of investigation.

The maximum phosphorus uptake in straw (7.75 and 8.33 kg ha^{-1}) was recorded with SRI) method (M_2), which was at par with transplanted rice (M_3) while, significantly superior over rest of the treatments during 2022 and 2023, respectively.

Among the nitrogen levels had significant effect in respect of phosphorus uptake by straw during both the years of investigations. Maximum amount of phosphorus uptake by straw (8.02 and 8.61 kg ha^{-1}) was recorded with application of 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5), which was at par with 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6) while, significantly superior over rest of the treatments. However, the minimum phosphorus uptake by straw (5.05 and 5.47 kg ha^{-1}) was recorded under control (N_1) during both the years of investigation. Uptake of phosphorus in grain and straw was significantly increased due to increased nitrogen. Increase in the uptake of phosphorus had significant impact by the application of nitrogen levels. Higher phosphorus uptake could be attributed to the higher availability of phosphorus in soil. These results were in conformity with the findings of Nishanth and Biswas (2008). The interaction effect of crop establishment methods of rice and nitrogen levels on potassium uptake in straw was found to be non-significant during both the years.

4.4.11 Potassium content in grin and straw of rice (%)

The data on potassium content in grain and straw in rice as influenced by establishment methods and nitrogen levels recorded for both the cropping seasons have been presented in Tables 3.

A pertaining of data clearly indicated that establishment methods and nitrogen levels had non-significant effect on potassium content in grain and straw in rice during both the years of experiment. However, maximum potassium content in grain and straw in rice (0.330 and 0.334 %, 1.557 and 1.573 % during 2022 and 2023 respectively) recorded under SRI method.

Among the nitrogen levels 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5) recorded maximum potassium content in grain and straw in rice (0.337 and 0.339 %, 1.587 and 1.602 % during 2022 and 2023 respectively) followed by 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6) during both years.

Potassium content in grain and straw as affected by different establishment methods and nitrogen levels were found to be non-significant during both the years of experimentation. Belder *et al*. (2005) also reported the similar type of responses.

4.4.12 Potassium uptake by grins and straw of rice (kg ha^{-1})

The data on potassium uptake by grain and straw in rice as influenced by establishment methods and nitrogen levels recorded both the cropping seasons have been presented in Tables 3, clearly indicated that establishment methods and nitrogen levels had significant effect on potassium uptake by grain and straw in rice during both the years of experiment.

Data further revealed that maximum potassium uptake by grain and straw in rice (18.3 and 19.8 kg ha^{-1}, 121.9 and 131.0 kg ha^{-1} during 2022 and 2023, respectively) recorded under SRI method which was significantly higher than rest of the treatments.

Among the nitrogen levels 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5) recorded maximum potassium uptake by grain and straw in rice (18.80 and 20.0 kg ha^{-1}, 127.2 and 134.4 kg ha^{-1} which was at par with 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6), while significantly superior over rest of the treatments during 2022 and 2023, respectively. However, the minimum uptake of potassium by grain and straw (11.5, 12.5 and 80.6, 87.5 kg ha^{-1}) was recorded under control (N_1) during both the years of investigation during 2022 and 2023 respectively).

Methods of establishment treatment affected the significant effects on uptake of potassium through grain and straw of rice crop. The maximum potassium uptake was recorded under SRI method. It was due to the fact that in SRI having younger seedling could be attributed to increased root volume and root weight which might have enabled more absorption area. Similar result was also found by Arunbabu and Satya (2014).

4.4.15 Protein content in grain (%)

Data pertaining to protein content in grain of rice as influenced by crop establishment methods and nitrogen levels have been given in Table 4.

A pertaining of data clearly indicated that establishment methods and nitrogen levels had non-significant effect on protein content in grain during both the years of experiment. However, maximum protein content in grain (7.52 % and 7.61 % during 2022 and 2023 respectively) recorded under SRI method.

Among the nitrogen levels 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5) recorded maximum protein content in grain (7.75 % and 7.88 % during 2022 and 2023 respectively) followed by application of 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6) during both years.

Protein content in grains as affected by different establishment methods and nitrogen levels were found to be non-significant during both the years of experimentation. Parashivamurthy *et al*. (2012) also reported the similar type of responses.

4.4.16: Protein yield of rice (kg ha^{-1})

The data related to protein yield (kg ha^{-1}) has been presented in Table 4. A critical analysis of data indicated that protein yield varied significantly due to crop establishment methods and nitrogen levels during both the years. In general protein yield was more in second year as compared to first year.

Significantly higher protein yield of rice grain (417.4 and 451.3 kg ha^{-1}) was recorded in SRI method (M1), which was statistically at par with transplanted rice (M_3) while, significantly superior over rest of the treatments during both the experimental years.

The nitrogen levels had significantly influenced by protein yield of rice grain during both the years of investigation. The higher protein yield (432.2 and 462.7 kg ha^{-1}) was observed with 60 % RDN through conventional Urea + 40 % RDN through Nano Urea (N_5), which was at par with 40 % RDN through conventional Urea + 60 % RDN through Nano Urea (N_6) and significantly superior over rest of the treatments during both the experimental years. However, significantly lowest protein yield was observed under control (N_1). Highest protein yield was recorded with 60 % RDN through conventional Urea + 40 % RDN through Nano Urea might be due to higher healthy grain yield and nitrogen content in grain.

Protein yield as affected by different establishment methods and weed management practices were found to be significant during both the years of experimentation. Parashivamurthy *et al.* (2012) also reported the similar type of responses.

4. Conclusions

It is concluded that, 60 % RDN through conventional Urea + 40 % RDN through Nano Urea which was at par with 40 % RDN through conventional Urea + 60 % RDN through Nano Urea treatment for different crop establishment methods and nitrogen levels was found better for all growth indices crop growth rate (CGR), relative growth rate (RGR), and net assimilation rate (NAR) under transplanted rice.

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Table 1. Nitrogen content (%) and Nitrogen uptake (kg/ha) of rice as influenced by crop establishment methods and nitrogen levels.

Treatments	**Nitrogen content (%)**				**Nitrogen uptake (kg ha^{-1})**			
	Grain		**Straw**		**Grain**		**Straw**	
	2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
Methods of establishment								
M_1: Direct Seeded Rice	1.183	1.197	0.431	0.436	47.25	50.29	25.26	26.83
M_2: System of Rice Intensification (SRI)	1.203	1.217	0.444	0.450	66.79	72.20	34.84	37.50
M_3: Transplanted Rice	1.193	1.207	0.436	0.441	62.52	67.35	33.52	35.95
SEm±	0.017	0.017	0.006	0.006	0.965	0.935	0.433	0.454
CD at 5%	NS	NS	NS	NS	3.89	3.77	1.75	1.83
N_1: Control	1.160	1.170	0.415	0.420	42.58	46.27	22.27	24.25
N_2: 100 % RDN through conventional Urea	1.170	1.180	0.431	0.436	56.57	60.56	30.30	32.43
N_3: 100 % RDN through Nano Urea	1.180	1.190	0.437	0.440	58.15	62.09	31.34	33.42

N_4: 80 % RDN through conventional Urea + 20 % RDN through Nano Urea	1.170	1.180	0.436	0.439	55.93	59.77	30.25	32.33
N_5: 60 % RDN through conventional Urea + 40 % RDN through Nano Urea	1.260	1.280	0.468	0.474	69.30	74.04	35.97	38.16
N_6: 40 % RDN through conventional Urea + 60 % RDN through Nano Urea	1.220	1.240	0.446	0.451	65.30	71.55	34.39	37.37
N_7: 20 % RDN through conventional Urea + 80 % RDN through Nano Urea	1.184	1.200	0.439	0.443	64.12	68.69	33.05	35.04
SEm±	0.026	0.026	0.010	0.010	1.651	1.856	0.949	0.987
CD at 5%	0.074	0.075	0.027	0.028	4.737	5.324	2.723	2.832

Table 2. Phosphorus content (%) and Phosphorus uptake (kg/ha) of rice as influenced by crop establishment methods and nitrogen levels.

Treatments	**Phosphorus content (%)**				**Phosphorus uptake (kg ha^{-1})**			
	Grain		**Straw**		**Grain**		**Straw**	
	2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
Methods of establishment								
M_1: Direct Seeded Rice	0.363	0.364	0.097	0.097	14.49	15.29	5.71	6.00
M_2: System of Rice Intensification (SRI)	0.373	0.377	0.099	0.100	20.74	22.37	7.75	8.33
M_3: Transplanted Rice	0.368	0.371	0.098	0.099	19.29	20.68	7.65	8.24
SEm±	0.005	0.005	0.001	0.001	0.287	0.325	0.101	0.104
CD at 5%	NS	NS	NS	NS	1.16	1.31	0.41	0.42
Nitrogen Levels								
N_1: Control	0.352	0.354	0.094	0.095	12.89	13.99	5.05	5.47
N_2: 100 % RDN through conventional Urea	0.360	0.363	0.094	0.095	17.44	18.66	6.89	7.34
N_3: 100 % RDN through Nano Urea	0.371	0.374	0.098	0.099	18.30	19.53	6.98	7.41
N_4: 80 % RDN through conventional Urea + 20 % RDN through Nano Urea	0.366	0.368	0.098	0.099	17.45	18.69	7.01	7.46

N$_5$: 60 % RDN through conventional Urea + 40 % RDN through Nano Urea	0.377	0.380	0.105	0.106	21.10	22.36	8.02	8.61
N$_6$: 40 % RDN through conventional Urea + 60 % RDN through Nano Urea	0.375	0.378	0.101	0.102	20.10	21.84	7.87	8.45
N$_7$: 20 % RDN through conventional Urea + 80 % RDN through Nano Urea	0.375	0.377	0.100	0.101	19.49	20.51	7.44	7.91
SEm±	0.008	0.008	0.002	0.002	0.525	0.594	0.200	0.215
CD at 5%	0.010	0.011	0.006	0.006	1.51	1.70	0.57	0.62

Table 3. Potassium content (%) and Potassium uptake (kg/ha) of rice as influenced by crop establishment methods and nitrogen levels.

Treatments	**Potassium content (%)**				**Potassium uptake (kg ha^{-1})**			
	Grain		**Straw**		**Grain**		**Straw**	
	2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
Methods of establishment								
M$_1$: Direct Seeded Rice	0.323	0.324	1.534	1.549	12.9	13.6	89.9	95.2
M$_2$: System of Rice Intensification (SRI)	0.330	0.334	1.557	1.573	18.3	19.8	121.9	131.0
M$_3$: Transplanted Rice	0.327	0.330	1.549	1.563	17.2	18.4	119.1	127.4
SEm±	0.005	0.005	0.022	0.022	0.28	0.24	1.60	1.50
CD at 5%	NS	NS	NS	NS	1.12	0.95	6.46	6.03
Nitrogen Levels								
N$_1$: Control	0.314	0.316	1.501	1.516	11.5	12.5	80.6	87.5
N$_2$: 100 % RDN through conventional Urea	0.315	0.317	1.527	1.542	15.2	16.3	107.3	114.6
N$_3$: 100 % RDN through Nano Urea	0.326	0.328	1.538	1.553	16.1	17.1	109.5	116.6
N$_4$: 80 % RDN through conventional Urea + 20 % RDN through Nano Urea	0.325	0.327	1.527	1.542	15.5	16.6	105.9	113.0

N_5: 60 % RDN through conventional Urea + 40 % RDN through Nano Urea	0.337	0.339	1.587	1.602	18.8	20.0	127.2	134.4
N_6: 40 % RDN through conventional Urea + 60 % RDN through Nano Urea	0.331	0.334	1.578	1.593	18.0	19.6	121.7	131.9
N_7: 20 % RDN through conventional Urea + 80 % RDN through Nano Urea	0.336	0.338	1.569	1.584	17.3	18.4	117.8	124.1
SEm±	0.007	0.007	0.034	0.034	0.47	0.49	3.00	3.32
CD at 5%	NS	NS	NS	NS	1.34	1.40	8.61	9.52

Table 4. Protein content in grain (%) and Protein yield of rice by crop establishment methods and nitrogen levels.

Treatments	**Protein content in grain (%)**		**Protein yield kg ha^{-1}**	
	2022	**2023**	**2022**	**2023**
Methods of establishment				
M_1: Direct Seeded Rice	7.39	7.48	295.0	314.3
M_2: System of Rice Intensification (SRI)	7.52	7.61	417.4	451.3
M_3: Transplanted Rice	7.46	7.55	398.7	435.9
SEm±	0.11	0.11	4.9	4.1
CD at 5%	NS	NS	19.8	16.7
Nitrogen Levels				
N_1: Control	7.25	7.31	265.4	289.2
N_2: 100 % RDN through conventional Urea	7.31	7.38	353.6	378.5
N_3: 100 % RDN through Nano Urea	7.38	7.44	363.5	388.1

N_4: 80 % RDN through conventional Urea + 20 % RDN through Nano Urea	7.31	7.38	349.6	373.5
N_5: 60 % RDN through conventional Urea + 40 % RDN through Nano Urea	7.75	7.88	433.2	462.7
N_6: 40 % RDN through conventional Urea + 60 % RDN through Nano Urea	7.63	7.75	408.1	447.2
N_7: 20 % RDN through conventional Urea + 80 % RDN through Nano Urea	7.56	7.69	400.7	429.3
SEm±	0.16	0.16	10.6	11.1
CD at 5%	NS	NS	30.3	31.7