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Effect of Nano Urea and Nano DAP on Growth, Yield and Nutrient Uptake of Transplanted Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Foliar nutrition is aimed to eliminate the problems of fixation and immobilization of nutrients. Hence, foliar nutrition is being recognized as a significant way of fertilizing modern agriculture, especially under rainfed conditions. Nano fertilizers because of smaller size and higher surface area are efficient as compared to conventional and produce better results when used in combined form. The experiment was laid out in Randomized complete block design with three replications. A field experiment was conducted in black clayey at Agricultural Research Station, Dhadesugur, during *Kharif* 2023. There were eight treatment combinations, consisting of different levels of conventional and nano fertilizers. RDF - 150:75:75 kg $N:P_2O_5:K_2O$ ha^{-1} and 50 % of N, entire P and K were applied as basal and remaining 50 % of N was top dressed at tillering and panicle initiation stage. RNR- 15048 variety of transplanted rice. Application of 50 % Rec. N with soil application + 50 % Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application recorded significantly higher number of green leaves, leaf area and leaf area index at harvest (52.7, 954.8 cm^2 $plant^{-1}$ and 4.77, respectively). It also produced higher panicle length (20.1 cm), number of grains $panicle^{-1}$ (242.3), panicle weight (3.73 g $plant^{-1}$), test weight (19.1 g) and grain yield (5578 kg ha^{-1}). Nutrient content and uptake also showed higher values for the same treatment. Combined application of conventional and nano fertilizers helped to increase growth, growth attributes like number of leaves, leaf area, leaf area index, yield attributes, yield, nutrient content and nutrient uptake of transplanted rice.

Keywords: Rice; foliar nutrition; nano urea; nano DAP; IFFCO.

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is an important cereal crop and a staple food for one third of the world population. It is necessary to increase its production and productivity in order to meet the growing demand of rice by increasing population. In the world, rice is being grown in an area of 165.03 m ha with a production of 777.46 m t with the productivity of 4704 kg ha^{-1}" [1]. "The total area under rice in India is 47.83 m ha with a production of 135.75 m t and productivity of 2.83 t ha^{-1}" [2]. "In Karnataka, rice is cultivated in command areas of Cauvery, Tungabhadra and Upper Krishna. The total area under rice cultivation is 13.97 lakh ha, with an annual production of 43.18 lakh tonnes and productivity of 3089 kg ha^{-1}" [3].

"In order to get higher yield farmers are applying higher dose of fertilizers which is causing a huge impact on environment. The NUE (Nutrient use efficiency) of basic nutrients like nitrogen (N) is 30-35 per cent and that of phosphorus (P) and potassium (K) is 18-20 per cent and 35-40 per cent, respectively. This has resulted into decrease in crop response to application of plant nutrients from 15 kg food grain kg^{-1} NPK during 1974-79 to less than 6 kg food grain kg^{-1} NPK in 2007-12" [4]. The diminished NUE threatens the future production and food security. Alternatively, fertilizer use efficiency (FUE), which is dependent on several factors including nutrient uptake and soil health, determines agricultural and environmental stability.

In order to complement the nutritional needs of crops, foliar spraying of nutrients coupled with basal applicational of conventional fertilizers provides a number of benefits. India's dry land tracts experience moisture deficits, which reduce production since fewer nutrients are available there. With this approach, nutrients are used more effectively and shortages are quickly corrected. New generation special fertilizers that are just intended for foliar feeding and fertilization have recently been launched.

"We need to use new generation special fertilizers like nano fertilizers which have emerged as an effective alternative solution for addressing crop nutritional deficiencies through enhanced bioavailability of nutrients and limited losses to the environment" [5]. Nano scale materials can enhance the fertilizer use efficiency while foliar application can meet the crop nutrient requirement effectively as per its need. Whereas, the nano fertilizers are called as nutrient vectors that are developed by using nano scale raw material substrates that are ranging from 1-100 nm [6] which have the ability to manipulate the materials to atom level, molecular and macromolecular scale. "Nano particles have a large surface area and have the ability to retain an abundant amount of nutrients and release them slowly and stably for a relatively longer time

so as to facilitate the nutrient absorption that corresponds to the crop requirement without any shortcomings associated with specialized fertilizer inputs" [7].

Nano urea and DAP fertilizers have been developed indigenously, for the first time in the world at IFFCO Nano Biotechnology Research Centre (NBRC), Kalol, Gujarat through a proprietary patented technology. Farmers are using urea and DAP fertilizers for soil as well as foliar application to crops. However, the efficacy is lower. Thus, the goal of the current study is to determine the effect of nano fertilizers on growth, yield and nutrient uptake of transplanted rice. Nano urea contains 4 per cent (40,000 ppm) nitrogen by weight in its nano form. In comparison to urea the uptake efficiency of nano urea is more than 80 per cent. It is thus, required in lesser measure compared to the conventional urea fertilizer to fulfil plant's nitrogen requirement. nano DAP contains about 8 per cent (80,000 ppm) of nitrogen and 16 per cent (1,60,000 ppm) of phosphorous. IFFCO nano DAP is prepared by nanotechnology, effectively fulfils crop nitrogen and phosphorous requirement when used as foliar spray.

2. MATERIALS AND METHODS

A field experiment was conducted during *kharif*, 2023 at Agricultural Research Station, Dhadesugur, on *Vertisol* having pH 8.07 and EC 0.43 dS m^{-1}. The soil was medium in available P_2O_5 (31.05 kg ha^{-1}), and low in organic carbon content (0.46) and available N (273.5 kg ha^{-1}) with high available K_2O content (374.8 kg ha^{-1}). The experimental site was located at a latitude of 15˚ 69´ N and longitude of 76˚ 89´ E and an altitude of 358 meters above mean sea level in Northern Dry Zone of Karnataka (Zone 3).

Total rainfall received during crop growth period was 335.2 mm from July to December 2023 and which was deficit of 87.1 mm of mean rainfall from past 10 years. The average maximum and minimum air temperature during crop growth period (July 2023 to December 2023) ranged from 30.6 to 33.7 ^{0}C and 18.2 to 22.8 ^{0}C, respectively. Maximum relative humidity (88.0 %) was observed in September as shown in Fig. 1.

The research was arranged in Randomized complete block design, there were eight treatment combination with different levels of conventional and nano fertilizers and those were replicated thrice. The treatment combinations are T_1: RDF with soil application, T_2: Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application, T_3: Rec. P through nano DAP with two applications (at tillering and panicle initiation stage) + Rec. N & K with soil application, T_4: Rec. N & P through nano urea and nano DAP, respectively with two applications (at tillering and panicle initiation stage) + Rec. K with soil application, T_5: 50 % Rec. N with soil application + 50 % Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application, T_6: 50 % Rec. P with soil application + 50 % Rec. P through nano DAP with two applications (at tillering and panicle initiation stage) + Rec. N & K with soil application, T_7: 50 % Rec. N & P with soil application + 50 % Rec. N & P through nano urea and nano DAP, respectively + Rec. K with soil application and T_8: Control. After the previous crop was harvested, the field was ploughed once again, followed by puddling. The field was prepped to a good seedbed and the fields were set out in preparation for transplanting. The variety RNR- 15048 was used. The basal application of fertilizers in the form of urea, SSP and MOP were applied as per treatments with recommended dose of 150:75:75 kg $N:P_2O_5:K_2O$ ha^{-1}. 50 % of N, entire P and K were applied as basal and remaining 50 % of N was top dressed at tillering and panicle initiation stage. The crop was transplanted on 12th August 2023 with a spacing of 20 cm × 10 cm. Growth parameters such as number of leaves and leaf area were recorded at interval of 30 days. Harvesting was done at physiological maturity of the crop. The panicles were harvested from the standing crop in the net plot area and were sun dried. The sun dried panicles were threshed, cleaned and yield parameters were recorded. The samples were collected harvest and dried at 65 ^{0}C in a hot air oven, powdered using a grinder, fitted with stainless steel bladders and preserved in polythene bags for further analysis of uptake of N, P and K as suggested by Jackson [8]. During the field experiment, a composite soil sample was collected from experimental plot before transplanting. After harvest of the crop, soils from each treated plot were taken separately. The collected soil samples were dried under shade, powdered using pestle and mortar and passed through 2 mm sieve and preserved for analysis. For organic carbon analysis, the 2 mm sieved soil samples were subjected for further grinding and passed through 0.2 mm sieve. Samples were analyzed for organic carbon, available nitrogen, phosphorus and potassium.

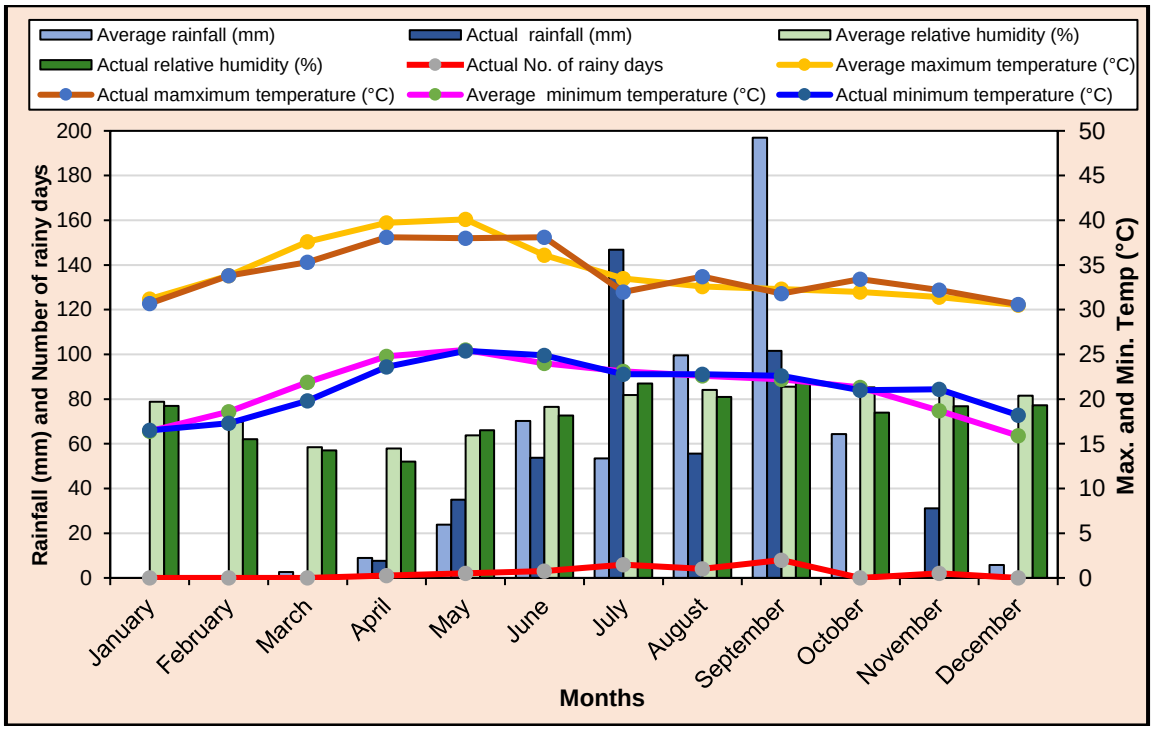

Fig. 1. Mean monthly meteorological data for the year 2023 and mean of the last 10 years (2014-2023) at ARS, Dhadesugur (Karnataka)

2.1 Statistical Analysis

The data collected from the experiment at different growth stages and at harvest were subjected to statistical analysis as described by Panse and Sukhatme [9]. The level of significance used for 'F' test was P=0.05. Critical Difference (CD) values were calculated at 5 per cent probability level if the F test will find to be significant.

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

Significantly maximum plant height was observed in 50 % Rec. N with soil application + 50 % Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application (119.7 cm) and followed by RDF with soil application (113.2 cm). The least plant height was observed in control (78.4 cm) (Fig. 2). Significantly higher number of leaves per plant were noticed in the treatment receiving 50 % Rec. N with soil application + 50 % Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application (T_5) (28.8, 63.1 and 52.7 at 60, 90 DAT and at harvest, respectively) (Table 1). Among nano DAP treatments, T_6 *i.e.,* 50 % Rec. P with soil application and 50 % nano DAP with two applications (at tillering and panicle initiation stage) + Rec. N & K with soil application recorded significantly higher number of green leaves at 60, 90 DAT and at harvest (26.2.4, 54.3 and 45.4, respectively) presented in Table 1. Similar results were reported by Asha Kiran et al. [10]. Combined application of conventional and nano fertilizers increased the availability of nitrogen and phosphorous which accelerated the enzymatic activity of photosynthesis, carbohydrate metabolism, synthesis of protein and cell division which in turn enhanced the plant height. As a consequence of increased plant height, the number of nodes and internodes increased which resulted in higher number of leaves.

Higher leaf area and leaf area index of transplanted rice were recorded by application of 50 % Rec. N with soil application + 50 % Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application (T_5) (492.1, 1203.8 and 954.8 cm^2 $plant^{-1}$ and 2.46, 6.02 and 4.77, at 60, 90 DAT and at harvest, respectively) as given in Table 1.

Whereas, among different nano DAP treatments, application of 50 % Rec. P with soil application

and 50 % nano DAP with two applications (at tillering and panicle initiation stage) + Rec. N & K with soil application (T_6) recorded significantly higher leaf area at 60, 90 DAT and at harvest (416.3, 1034.8 and 815.2 cm^2 $plant^{-1}$, respectively) and leaf area index (2.08, 5.17 and 4.08, respectively at 60, 90 DAT and at harvest). As a result of foliar spray of nano fertilizers along with basal dose of conventional fertilizers, the availability of nitrogen and phosphorous increased. The increased availability resulted in increased plant height, number of leaves, leaf area and finally leaf area index. These findings were in accordance with Anushka et al. [11].

3.2 Yield Attributes

With respect to panicle length and test weight, there was no significant difference between the treatments presented in Table 2. Whereas, among different treatments, T_5 *i.e.,* 50 % Rec. N with soil application + 50 % Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application recorded numerically higher panicle length (20.1 cm) and test weight (19.1 g). Significantly higher number of grains per panicle, panicle weight and grain yield were recorded in 50 % Rec. N with soil application + 50 % Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application (T_5) (242.3, 3.73 g and 5578 kg ha^{-1}, respectively). Whereas, among nano DAP treatments, application of 50 % Rec. P with soil application and 50 % nano DAP with two applications (at tillering and panicle initiation stage) + Rec. N & K with soil application (T_6) recorded significantly higher number of grains per panicle, panicle weight and grain yield (217.7, 3.45 g and 5126 kg ha^{-1}, respectively) and found on par with 50 % Rec. N & P with soil application + 50 % Rec. N & P through nano urea and nano DAP, respectively (at tillering and panicle initiation stage) + Rec. K with soil application (T_7) (213.2, 3.41 g and 5072 kg ha^{-1}, respectively). Similar results were reported by Midde *et al.* [12]. Combined application of conventional and nano fertilizers (nano urea and DAP) ensured optimum and balanced nutrient availability throughout the crop period especially during the critical stages of crop. This is due to smaller size and larger effective surface area of nano particles which can easily penetrate into the plant and lead to better uptake of nitrogen and phosphorous. The higher uptake results in optimal growth of plant parts and metabolic processes like photosynthesis that increase photosynthates accumulation and translocation to the economically productive parts of the plant which results in increased biomass, yield attributing characters and finally yield by amplifying the translocation of assimilates to seeds.

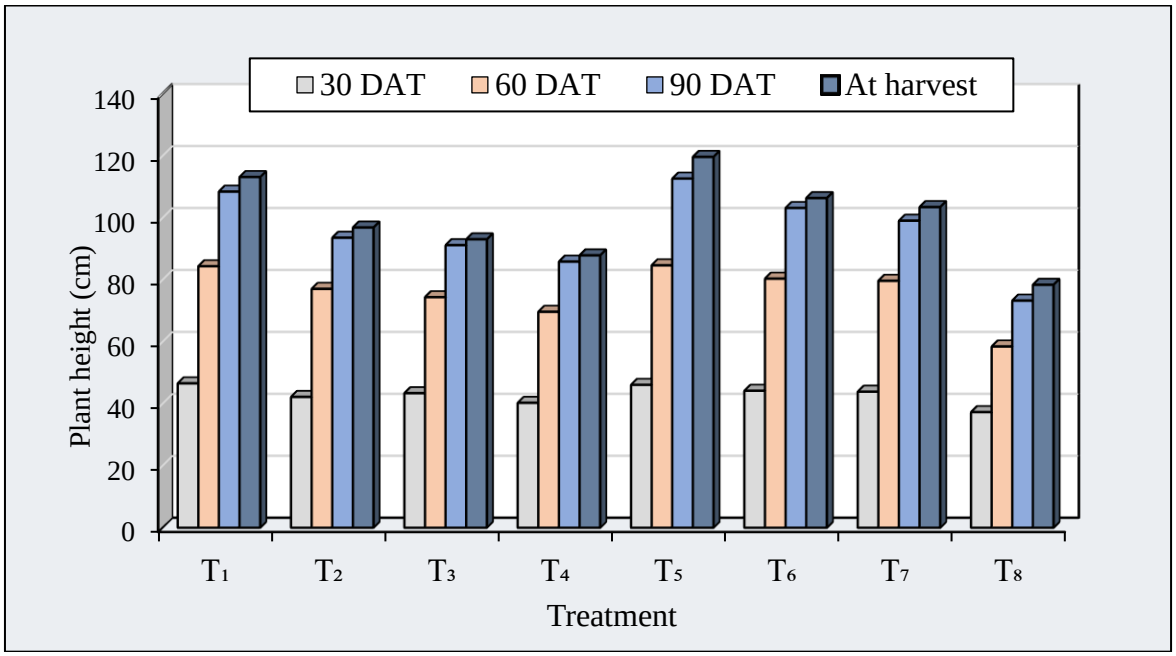

Fig. 2. Plant height of transplanted rice at different growth stages as influenced by application of different level of conventional and nano fertilizers

Table 1. Number of green leaves per plant, leaf area and leaf area index of transplanted rice as influenced by application of different levels of conventional and nano fertilizers

Treatment	Number of green leaves per plant				Leaf area (cm^2 $plant^{-1}$)				Leaf area index			
	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest
T_1	9.7	28.3	59.5	49.5	109.1	469.5	1115.6	878.8	0.55	2.35	5.58	4.39
T_2	8.9	25.1	49.5	40.2	100.5	379.8	888.1	671.3	0.50	1.90	4.44	3.36
T_3	9.1	24.7	48.3	38.9	102.4	341.0	805.6	598.3	0.51	1.71	4.03	2.99
T_4	8.3	21.7	46.6	37.6	93.4	302.7	720.4	531.8	0.47	1.51	3.60	2.66
T_5	9.5	28.8	63.1	52.7	106.9	492.0	1203.8	954.8	0.53	2.46	6.02	4.77
T_6	9.3	26.2	54.3	45.4	104.6	416.3	1034.8	815.2	0.52	2.08	5.17	4.08
T_7	9.2	25.5	52.7	44.3	103.1	392.5	974.8	769.4	0.52	1.96	4.87	3.85
T_8	7.9	15.5	29.5	25.8	88.9	223.0	555.3	435.1	0.44	1.12	2.78	2.18
S.Em.±	**0.4**	**0.7**	**1.9**	**1.5**	**4.5**	**10.3**	**23.5**	**19.9**	**0.02**	**0.05**	**0.12**	**0.10**
C.D. (P=0.05)	**NS**	**2.0**	**5.7**	**4.7**	**NS**	**31.1**	**71.3**	**60.3**	**NS**	**0.16**	**0.36**	**0.30**

Table 2. Yield attributes and grain yield of transplanted rice as influenced by application of different levels of conventional and nano fertilizers

Treatment	Panicle length (cm)	Number of grains $panicle^{-1}$	Panicle weight (g)	Test weight (g)	Grain yield (kg ha^{-1})
T_1	19.6	229.5	3.52	18.8	5342
T_2	19.1	207.2	3.30	18.5	4821
T_3	18.8	203.1	3.13	18.4	4603
T_4	18.6	193.4	2.95	18.1	4310
T_5	20.1	242.3	3.73	19.1	5578
T_6	19.2	217.7	3.45	18.6	5126
T_7	18.9	213.2	3.41	18.6	5072
T_8	18.5	178.9	2.73	17.7	2681
S.Em.±	**0.7**	**3.2**	**0.06**	**0.7**	**69**
C.D. (P=0.05)	**NS**	**9.8**	**0.19**	**NS**	**211**

Table 3. Total nutrient content and uptake by transplanted rice as influenced by the application of different levels conventional and nano fertilizers

Treatment	Total nutrient content (%)			Total nutrient uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
T_1	2.08	0.69	1.91	119.2	39.4	115.9
T_2	1.91	0.62	1.78	98.4	31.7	95.2
T_3	1.89	0.61	1.74	92.3	29.8	90.1
T_4	1.77	0.55	1.65	81.5	25.2	79.7
T_5	2.17	0.73	1.95	130.5	43.3	123.8
T_6	1.99	0.66	1.85	109.2	36.1	107.3
T_7	1.95	0.64	1.80	105.6	34.3	103.1
T_8	1.64	0.47	1.54	49.4	14.2	50.9
S.Em.±	**0.03**	**0.02**	**0.02**	**2.1**	**1.0**	**1.8**
C.D. (P=0.05)	**0.09**	**0.06**	**0.07**	**6.4**	**3.1**	**5.4**

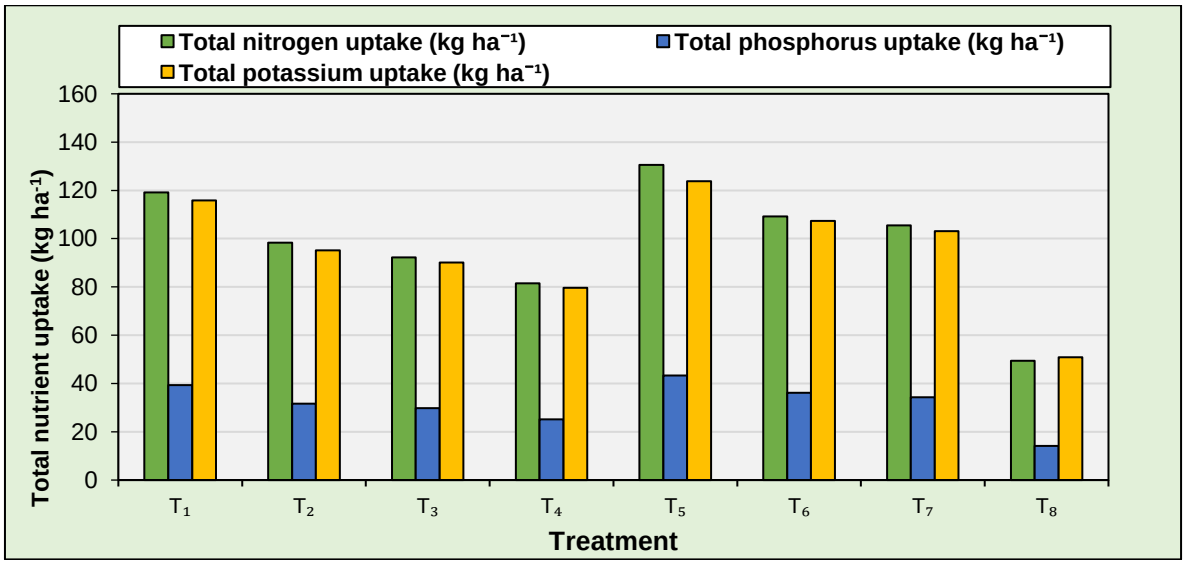

Fig. 3. Total nutrient uptake (%) by transplanted rice at harvest as influenced by application of different levels of conventional and nano fertilizers

3.3 Nutrient Content and Uptake by Plants

The data on nutrient content and uptake of transplanted rice as influenced by the application of different levels of conventional and nano fertilizers are presented in Table 3 and Fig. 2. Among all the treatments, significantly higher concentration of nitrogen, phosphorus and potassium in rice plant were recorded in treatment T_5 *i.e.,* 50% Rec. N with soil application + 50% Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application (2.17, 0.73 and 1.95 %, respectively) and it was found on par to T_1 (RDF with soil application) (2.08, 0.69 and 1.91%, respectively). Whereas significantly lower concentration of nitrogen, phosphorus and potassium in rice plant were noticed in T_8: Control (1.64, 0.47 and 1.54%, respectively). The uptake of major nutrients *viz.,* nitrogen, phosphorus and potassium were recorded significantly higher in T_5: 50% Rec. N with soil application + 50 % Rec. N through nano urea with two applications (at tillering and panicle initiation stage) + Rec. P & K with soil application (130.5, 43.3 and 123.8 kg ha^{-1}, respectively). The increase in nutrient uptake was due to the foliar application of nano fertilizers which have higher surface area and smaller particle size, less than the pore size of root and leaves of the plant which can increase their penetration into the plant from applied surface and improve nutrient uptake. The results are in accordance with the findings of Gupta et al. [13].

4. CONCLUSION

Combined application of conventional and nano fertilizers *i.e.,* 50% Rec. N with soil application + 50% Rec. N through nano urea with two applications, one at tillering and another at panicle initiation stage + Rec. P & K with soil application is best to increase growth attributes, yield parameters and nutrient uptake by the plants with effective management of nitrogen requirement of transplanted rice.

Similarly, among nano DAP treatments, 50% Rec. P with soil application and 50% nano DAP with two applications, one at tillering and another at panicle initiation stage + Rec. N & K with soil application recorded significantly increase growth attributes, yield parameters and nutrient uptake by the plants.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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