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Jagriti Patel
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

K Tedia
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

LK Srivastava
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Jyoti Bala
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Gourav Jatav
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

VN Mishra
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:
Jagriti Patel
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Effect of nano nitrogen on growth and yield of rice in *Vertisols* of Chhattisgarh

Jagriti Patel, K Tedia, LK Srivastava, Jyoti Bala, Gourav Jatav and VN Mishra

Abstract
A field experiment was carried out in research farm, IGKV, Raipur, Chhattisgarh, India during the *kharif* season of 2020 and 2021 to study the effect of nano nitrogen on the growth and production of rice. It was laid down in a randomized block design (RBD) consisting twelve treatments and three replications. The different treatment combinations were T_1 – 0% N (control), T_2 - 50% RDN, T_3 – 75% RDN, T_4 – 100% NPK (RDF - 120:60:40 kg ha^{-1}), T_5 – 0% N + 2 sprays of nano N @ 4 ml l^{-1}, T_6 – 0% N + 2 sprays of nano N @ 8 ml l^{-1}, T_7 – 50% N + 2 sprays of nano N @ 4 ml l^{-1}, T_8 – 50% N + 2 sprays of nano N @ 8 ml l^{-1}, T_9 – 75% N + 2 sprays of nano N @ 4 ml l^{-1}, T_{10} – 75% N + 2 sprays of nano N @ 8 ml l^{-1}, T_{11} – 50% N + 2 sprays of 2% urea and T_{12} – 50% N + 3 sprays of 2% urea. The results proved that the combined application of conventional and nano nitrogen had a positive influence on most of the growth parameters. The treatments with 100% RDF (T_4), 75% N + 2 sprays of nano N @ 8 and 4 ml l^{-1} (T_{10} and T_9), 50% N + 2 sprays of nano N @ 8 and 4 ml l^{-1} (T_8 and T_7) and 50% N + 3 sprays of 2% urea (T_{12}) obtained significantly higher grain yield over the others in both the seasons. Also, the higher B:C ratio was obtained by the application of nano N combined with 50 and 75% RDN and 100% RDF.

Keywords: Nano N, foliar application, rice, growth parameters, B:C ratio

1. Introduction

Nearly 3 billion people, or roughly 50% of the world's population, eat rice as a daily staple. Rice is grown on around 164.19 million hectares of land and is produced in the globe in an estimated 756.74 million tonnes year (FAOSTAT, 2020) [5], which is greater than any other crop in the world. Nearly 90% (89.14%) of this is produced in Asia, with China and India making up the majority of the continent's production. After China, India is the world's largest exporter of rice and the second-largest producer of the grain. The Indian state Chhattisgarh is known as the 'rice bowl of India' because it is a major paddy-growing state. The crop occupies an average of 3.6 million ha in the state, of which 20–30% of the rice is grown in the low-lying areas of *Vertisol*. (Pandey *et al*.) [10].

In light of the above statistics, it is clear that in order to meet the demands of the expanding global population, the production of rice needs to be greatly increased. However, challenges faced in scaling rice production includes reduction in the amount of arable land, climate change, accelerated disasters, the high cost of fertilizers, and the reducing efficiencies of fertilizers used in agricultural systems (Wu *et al.*, 2016) [15]. Nitrogen is one of the most essential nutrients for plant growth and yield. Nitrogen is a primary constituent of chlorophyll molecule, which imparts green colour to the plants. Compared to other crops, cereal crops require higher amount of nitrogen for their growth and grain production (Sahrawat, 2000) [12]. Consequently, nitrogen (N), which is the nutrient that most severely limits productivity in the production of irrigated rice worldwide, is extremely important for the growth of rice (Samonte *et al.*, 2006) [13]. The major source of nitrogen for rice in lowland is soil N, biological nitrogen fixation and fertilizer N. The nitrogen in soil gets frequently lost through plant removal, leaching and ammonia volatilization. These field losses are a significant issue since they result in a number of processes and seriously endanger the ecosystem. Therefore, it is a challenging task to achieve a higher nitrogen use efficiency.

In order to overcome all these drawbacks, nanotechnology might turn out to be the right choice. Nanotechnology focuses on the comprehension and manipulation of matter at scales between 1 and 100 nanometers (one nanometer equals one billionth of a metre). The nanoscale particles show exceptional properties which are usually not possible in the case of normal size particles.

Nano fertilizers may become effective tools in agriculture for better nutrient management as these nano materials possess more penetration capacity, surface area and use efficiency which avoid residues in environment. Accordingly, nano fertilizers are a cutting-edge product that may be used to boost output without harming the environment since they triple nutrient usage efficiency (NUE) while also enhancing plant tolerance to stress (Manjunatha *et al*., 2016) [9].
Therefore, the present study aimed at study the effect of nano nitrogen on rice growth and yield which aims to preserve the environment and reduce the cost of plant production.

2. Materials and Methods

The experiment was conducted at research farm of Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh, India during *Kharif* season of the year 2020 and 2021 to investigate the response of nano nitrogen application on the growth and yield of rice. The soil of the experimental area was clayey in nature falling under the category of *Vertisol*, which is a fine, hyperthermic, montmorillonitic chromustert soil. Locally, the soil is known as *Kanhar* and is classified under Arang II series. The experimental soil was clayey in texture, neutral in reaction (7.2) and non-saline in nature (0.38 dS m^{-1}). The organic matter (0.45%) and available nitrogen (221.30 kg ha^{-1}) were low in status. On the other hand, the available phosphorus (15.5 kg ha^{-1}) was found medium and available potassium (398.70 kg ha^{-1}) was found at higher status in the soil. Rice (variety – Rajeshwari) was used as test crop in the experiment. The experimental land was prepared thoroughly by ploughing twice with the help of cultivator and divided into plots of size 4 x 5 m. The plots were cleaned up by collecting and removing weeds and stubbles of previous crop. The plots were labelled uniformly and were laid down as per the design of the experiment. The trial was laid down in a randomized block design (RBD) corresponding to 12 treatments and three replications. The treatments were T_1 – 0% N (control), T_2 - 50% RDN, T_3 – 75% RDN, T_4 – 100% NPK (RDF - 120:60:40 kg ha^{-1}), T_5 – 0% N + 2 sprays of nano N @ 4 ml l^{-1}, T_6 – 0% N + 2 sprays of nano N @ 8 ml l^{-1}, T_7 – 50% N + 2 sprays of nano N @ 4 ml l^{-1}, T_8 – 50% N + 2 sprays of nano N @ 8 ml l^{-1}, T_9 – 75% N + 2 sprays of nano N @ 4 ml l^{-1}, T_{10} – 75% N + 2 sprays of nano N @ 8 ml l^{-1}, T_{11} – 50% N + 2 sprays of 2% urea and T_{12} – 50% N + 3 sprays of 2% urea. All the treatments consisted a common dose of 100% recommended dose of P and K. Urea, Single super phosphate (SSP), Muriate of potash (MOP) and nano nitrogen were used as fertilizers. The urea, SSP and MOP were administered through soil application as basal dose whereas, nano N and urea were given 2 times (at tillering and panicle initiation stage, respectively) through foliar application, as per the treatments. The initial and after harvest soil samples were analyzed using standard protocols to determine the physico-chemical properties of soil. For agronomic observations, five hills at random from each plot were selected and their mean was noted as the final reading of the respective plot. The gross return $hectare^{-1}$, net return $hectare^{-1}$ and benefit cost ratio were recorded as per the formulas given by Tomar and Tiwari, 1990. The yield data collected from field and those recorded in the laboratory were subjected to statistical analysis. The analysis of variance approach was used to examine the analytical data in this experiment as described by Gomez and Gomez (1984) [7].

3. Results and Discussion

The treatments comprising of both conventional urea and its combination with foliar application of nano nitrogen had a significant effect on the final plant height and number of tillers per plant of the rice plants in both the years of experimentation (Table 1). The data on plant height varied between 101.17 and 118.20 cm (in *kharif* 2020) and 102.06 and 117.95 cm (in *kharif* 2021). The highest plant height was obtained by 100% RDF (T_4) which was at par with all the treatments consisting foliar sprays in combination with 50 and 75% RDN (T_7, T_8, T_9, T_{10}, T_{11} and T_{12}) and 75% RDN (T_3). The highest number of tillers per plant (7.73 and 7.87) was obtained by recommended dose of fertilizer (T_4) while the least number of tillers i.e., 4.13 and 4.33 were obtained in control (T_1) in *kharif* 2020 and *kharif* 2021, respectively. The treatments with 75% RDN with 2 sprays of nano N @4 and 8 ml l^{-1} (T_9 and T_{10}) and 50% RDN with 2 and 3 sprays of urea (T_{11} and T_{12}) were found significantly similar to 100% RDF and superior over the other treatments. The panicle length and number of grains per panicle were also found statistically significant by the application of different treatment combinations (Table 2). The range in which the length of panicle varied was 18.57 - 24.20 cm (*kharif* 2020) and 18.56 – 24.39 cm (*kharif* 2021). The longest panicles were found in 100% RDF (T_4) followed by 75% N + 2 sprays of nano N @ 8 and 4 ml l^{-1} (T_{10} and T_9), respectively whereas, the least was recorded in T_1 – control. T_9 and T_{10} were found at par with the 100% RDF and significantly superior to other treatments in both seasons. Similar results were found in the case of number of grains per panicle which varied significantly from 116 to 157.93 (*kharif* 2020) and from 120.27 to 160.07 (*kharif* 2021). The treatments 75% RDN with 2 sprays of nano N @ 4 and 8 ml l^{-1} in T_9 and T_{10} were at par with each other and with the 100% RDF (T_4) and significantly superior to other treatments. Furthermore, the test weight was influenced non-significantly by the application of different treatment combinations (Table – 3). The range in which the test weight lied was from 30.38 to 32.31 g in *kharif* 2020 and 30.85 to 32.17 g in *kharif* 2021. The application of 75% RDN + 2 sprays of nano N @4 ml l^{-1} obtained slightly higher test weight while the lowest was observed in control (T_1) in *kharif* 2020 and *kharif* 2021. The results clearly indicates that the combined application of nano and conventional source of nitrogen encouraged the rice plants to absorb and utilize the nutrients efficiently. It may have created a consistent nutritional balance for various growth phases of the rice plant, particularly in the case of nanomaterial, which accelerates crop growth and supports crop growth metabolism and development. Present results are concomitant with the findings of Benzon *et al*. (2015) [3], Manik *et al.* (2016) [8], Abdel-Aziz *et al*. (2016) [1], Rathnayaka *et al*. (2018) [11] Elavarsan *et al*. (2021) [4] and Gharieb (2021) [6].
Application of different treatment combinations resulted in a significant increase in grain and straw yield compared to control treatment in both the seasons (Table 4). Addition of 120 kg N ha^{-1} (100% RDN) as soil application noticeably produced the highest grain yield followed by 90 kg N + 2 foliar sprays of nano N @ 8 ml l^{-1} during the *kharif* 2020 and 2021. The application of 50 and 75% N in combination with foliar sprays of urea and nano N were at par with 100% RDF in both seasons. Additionally, the plants treated with 75% RDN (T_3), 50% N +2 sprays of nano N @4 and 8 ml l^{-1} (T_7 and T_8), 75% N + 2 sprays of nano N @4 and 8 ml l^{-1} (T_9 and

T_{10}) and 50% N + 2 and 3 sprays of urea (T_{11} and T_{12}) were at par with each other in the two seasons. The straw yield ranged between 35.41 to 66.62 q ha^{-1} and 36.47 to 71.56 q ha^{-1} in *kharif* seasons of 2020 and 2021, respectively. The application of 75% N + 2 sprays of nano N @ 8 ml l^{-1} (64.04 q ha^{-1}) and 75% N + 2 sprays of nano N @ 4 ml l^{-1} (63.38 q ha^{-1}) and 50% N + 3 sprays of 2% urea (61.78 q ha^{-1}) were found at par with 100% RDF (66.62 q ha^{-1}) in *kharif* 2020. However, in *kharif* 2021, the highest straw yield was obtained in 100% RDF (T_4:71.56 q ha^{-1}), and significantly superior to the others, while the minimum straw yield was recorded in the control (36.47 q ha^{-1}). The higher grain and straw yield might be obtained because of the effective utilization of N resources. The N in nano form especially provided at the later phases of the plant life cycle might also have resulted in higher yield since that might have resulted in availability of nutrient for a longer period of time. In addition to this, the nano particles being very small in size are able to easily penetrate through the epidermis of foliage making them highly efficient. Similar results were obtained by Alam *et al.* (2010) [2], Manik *et al.* (2016) [8] Elavarasan *et al.* (2021) [4] and Gharieb (2021) [6].

The economic performance of different treatment combinations was evaluated through economic analysis and the data of the two seasons were pooled for the final results. The data indicated that the highest gross return (₹ 1,14,366 ha^{-1}) and net return ₹ 74,207 ha^{-1} were obtained from T_4 with the application of 120 kg N ha^{-1} followed by in 75% N + 2 nano N sprays @8 ml l^{-1} (T_{10}) and 75% N + 2 sprays of nano N @ 4 ml l^{-1} (T_9). The control (T_1) with no nitrogen application had the lowest gross return (₹ 59,881 ha^{-1}) and net return (₹ 21,246 ha^{-1}). It was also observed that the Benefit: Cost (B:C) ratio was maximized in 100% RDF (T_4) which was followed by the application of 75% N + sprays of nano N @ 4 ml l^{-1} (T_9). Also, the application of 75% N with 2 sprays of nano N @ 4 and 8 ml l^{-1} (T_9 and T_{12}) and 50% N with 2 and 3 sprays of urea (T_{11} and T_{12}) obtained B: C ratio ranging between 1.63 to 1.68 which were comparable to T_4). The higher cost incurred on wages of labour employed for spraying of fertilizer led to the lower B: C ratio in these treatments. These results were corroborated with the findings of Manik *et al.* (2016) [8]. However, Yadav *et al.*, (2021) [16] reported highest B: C ratio with the application of 50% N with 2 sprays of nano N.

Table 1: Effect of different combination of N fertilizer on plant height and number of tillers per plant of rice in 2020 and 2021

Treatment details	Plant height (cm)		Number of tillers per plant	
	2020	2021	2020	2021
T_1 – 0% N (Control)	101.17^c	102.06^e	4.13^e	4.33^e
T_2 - 50% RDN	110.17^b	110.26^{bcd}	6.00^d	6.13^d
T_3 – 75% RDN	115.63^{ab}	115.83^{abc}	7.00^{abc}	7.07^{bc}
T_4 – 100% NPK (RDF - 120:60:40)	118.20^a	117.95^a	7.73^a	7.87^a
T_5 – 0% N + 2 sprays of nano N @ 4 ml l^{-1}	109.15^b	109.17^d	6.27^{cd}	6.67^{cd}
T_6 – 0% N + 2 sprays of nano N @ 8 ml l^{-1}	109.34^b	109.61^{cd}	6.40^{bcd}	6.80^{cd}
T_7 – 50% N + 2 sprays of nano N @ 4 ml l^{-1}	114.76^{ab}	115.71^{abc}	6.53^{bcd}	6.87^{bcd}
T_8 – 50% N + 2 sprays of nano N @ 8 ml l^{-1}	115.42^{ab}	115.71^{abc}	6.60^{bcd}	6.93^{bc}
T_9 – 75% N + 2 sprays of nano N @ 4 ml l^{-1}	117.54^a	116.18^{ab}	7.13^{ab}	7.33^{abc}
T_{10} – 75% N + 2 sprays of nano N @ 8 ml l^{-1}	117.73^a	117.23^a	7.20^{ab}	7.60^{ab}
T_{11} – 50% N + 2 sprays of 2% urea	114.93^{ab}	115.35^{abcd}	7.07^{abc}	7.20^{abc}
T_{12} – 50% N + 3 sprays of 2% urea	116.04^{ab}	116.01^{ab}	7.07^{abc}	7.27^{abc}
SEM±	2.47	2.17	0.28	0.26
CD (p = 0.05)	7.26	6.37	0.81	0.75

Table 2: Effect of different combination of N fertilizer on length of panicle and number of grains per panicle of rice in 2020 and 2021

Treatment details	Length of panicle (cm)		Number of grains per panicle	
	2020	2021	2020	2021
T_1 – 0% N (Control)	18.57^d	18.65^e	116.00^g	120.27e
T_2 - 50% RDN	20.09^{cd}	20.87^{cd}	130.53^{ef}	131.73^{cd}
T_3 – 75% RDN	21.30^{bc}	21.51^{bcd}	147.40^{bc}	147.13^b
T_4 – 100% NPK (RDF - 120:60:40)	24.20^a	24.39^a	157.93^a	160.07^a
T_5 – 0% N + 2 sprays of nano N @ 4 ml l^{-1}	19.79^{cd}	19.72^{de}	123.40^{fg}	126.20^{de}
T_6 – 0% N + 2 sprays of nano N @ 8 ml l^{-1}	20.03^{cd}	19.83^{de}	125.40^f	127.40^{de}
T_7 – 50% N + 2 sprays of nano N @ 4 ml l^{-1}	21.35^{bc}	21.33^{bcd}	137.87^{de}	138.33^{bc}
T_8 – 50% N + 2 sprays of nano N @ 8 ml l^{-1}	21.41^{bc}	21.99^{bc}	136.53^{de}	139.33^{bc}
T_9 – 75% N + 2 sprays of nano N @ 4 ml l^{-1}	22.83^{ab}	23.05^{ab}	153.40^{ab}	159.53^a
T_{10} – 75% N + 2 sprays of nano N @ 8 ml l^{-1}	23.19^{ab}	23.25^{ab}	155.93^a	160.07^a
T_{11} – 50% N + 2 sprays of 2% urea	21.54^{bc}	22.13^{bc}	138.33^{de}	139.33^{bc}
T_{12} – 50% N + 3 sprays of 2% urea	22.03^{abc}	22.05^{bc}	140.07^{cd}	142.67^b
SEM±	0.78	0.65	2.76	3.33
CD (p = 0.05)	2.29	1.92	8.10	9.78

Table 3: Effect of different combination of N fertilizer on test weight of rice in 2020 and 2021

Treatment details	Test weight (g)	
	2020	2021
T_1 – 0% N (Control)	30.38	31.42
T_2 – 50% RDN	31.67	31.05

T_3 – 75% RDN	31.23	31.70
T_4 – 100% NPK (RDF - 120:60:40)	31.73	31.18
T_5 – 0% N + 2 sprays of nano N @ 4 ml l^{-1}	30.78	31.22
T_6 – 0% N + 2 sprays of nano N @ 8 ml l^{-1}	31.94	30.85
T_7 – 50% N + 2 sprays of nano N @ 4 ml l^{-1}	31.19	31.80
T_8 – 50% N + 2 sprays of nano N @ 8 ml l^{-1}	32.31	31.48
T_9 – 75% N + 2 sprays of nano N @ 4 ml l^{-1}	32.13	32.17
T_{10} – 75% N + 2 sprays of nano N @ 8 ml l^{-1}	31.87	31.52
T_{11} – 50% N + 2 sprays of 2% urea	31.38	31.80
T_{12} – 50% N + 3 sprays of 2% urea	31.80	31.15
SEM±	0.66	0.61
CD (p = 0.05)	NS	NS

Table 4: Effect of different combination of N fertilizer on grain and straw yield of rice in 2020 and 2021

Treatment details	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	2020	2021	2020	2021
T_1 – 0% N (Control)	30.50^{d}	31.23^{g}	35.41^{e}	36.47^{g}
T_2 - 50% RDN	45.50^{c}	45.82^{d}	51.17^{c}	51.17^{de}
T_3 – 75% RDN	53.18^{b}	54.13^{c}	59.51^{b}	62.27^{bc}
T_4 – 100% NPK (RDF - 120:60:40)	58.24^{a}	59.67^{a}	66.62^{a}	71.56^{a}
T_5 – 0% N + 2 sprays of nano N @ 4 ml l^{-1}	34.88^{d}	36.70^{ef}	39.99^{de}	42.51^{f}
T_6 – 0% N + 2 sprays of nano N @ 8 ml l^{-1}	37.64^{d}	39.37^{e}	43.67^{cd}	46.45^{ef}
T_7 – 50% N + 2 sprays of nano N @ 4 ml l^{-1}	54.57^{ab}	55.13^{abc}	61.58^{b}	63.59^{bc}
T_8 – 50% N + 2 sprays of nano N @ 8 ml l^{-1}	55.23^{ab}	55.47^{abc}	61.23^{b}	60.25^{bc}
T_9 – 75% N + 2 sprays of nano N @ 4 ml l^{-1}	57.38^{ab}	57.55^{abc}	63.38^{ab}	64.28^{bc}
T_{10} – 75% N + 2 sprays of nano N @ 8 ml l^{-1}	58.04^{ab}	58.08^{ab}	64.04^{a}	65.57^{b}
T_{11} – 50% N + 2 sprays of 2% urea	54.11^{ab}	54.88^{abc}	60.78^{b}	58.92^{c}
T_{12} – 50% N + 3 sprays of 2% urea	55.45^{ab}	55.07^{abc}	61.78^{ab}	60.30^{bc}
SEM±	1.70	1.83	1.71	1.89
CD (p = 0.05)	4.97	5.37	5.00	5.55

Table 5: Effect of different combination of N fertilizer on grain and straw yield of rice in 2020 and 2021

Treatments	Gross return (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
T_1 – 0% N (Control)	59881	38635	21246	0.55
T_2 - 50% RDN	88577	39397	49180	1.25
T_3 – 75% RDN	104092	39778	64314	1.62
T_4 – 100% NPK (RDF - 120:60:40)	114366	40159	74207	1.85
T_5 – 0% N + 2 sprays of nano N @ 4 ml l^{-1}	69431	40435	28996	0.72
T_6 – 0% N + 2 sprays of nano N @ 8 ml l^{-1}	74698	41635	33063	0.79
T_7 – 50% N + 2 sprays of nano N @ 4 ml l^{-1}	106414	41197	65217	1.58
T_8 – 50% N + 2 sprays of nano N @ 8 ml l^{-1}	107376	42397	64979	1.53
T_9 – 75% N + 2 sprays of nano N @ 4 ml l^{-1}	111482	41578	69904	1.68
T_{10} – 75% N + 2 sprays of nano N @ 8 ml l^{-1}	112640	42778	69861	1.63
T_{11} – 50% N + 2 sprays of 2% urea	105725	40071	65654	1.64
T_{12} – 50% N + 3 sprays of 2% urea	107196	40409	66788	1.65

4. Conclusion

The application of nano fertilizers in agriculture is still in its primitive stage of development and this research is a maiden attempt to evaluate the performance of nano nitrogen alongside conventional urea in rice crop. It can be concluded from the above study that the treatments with different combination of conventional and nano N sources had a significant effect in improving the yield and yield attributing characters (except test weight) of rice. The foliar application of nano N in combination with 75% recommended dose of conventional urea was able to give remarkably high yield which is directly comparable to 100% RDF. The treatments with 50% RDN mixed with foliar sprays of nano N and conventional urea were also able to give higher yields. The application of 100% RDF attained highest B:C ratio but other treatments with foliar sprays combined with 50 and 75% also gave higher returns. Hence with the application of nano N, we can save upto 50% dose of recommended dose of nitrogen fertilizers.

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