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Effect of Precision Nitrogen Management using Nano Urea and Optical Sensor on the Nitrogen Use Efficiency of Basmati Rice and on the Soil properties under Different Methods of Establishment

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ABSTRACT: At the Rice Research Station, Kaul (Kaithal) of CCS Haryana Agricultural University, Hisar, a field experiment was carried out in the *kharif* seasons of 2022 and 2023 to study the precision nitrogen management of basmati rice under two distinct crop establishment methods using nano urea and optical sensors. The RBD factorial design was used to set up the experiment. The major plot treatments were direct seeded (DSR) and transplanted (TPR), and there were 10 distinct precision nitrogen management techniques spread among three replications of sub-plots. In both experiment years, crop establishment techniques had no effect on the soil's physiochemical characteristics or nitrogen use efficiency following crop harvest. The various precision nitrogen management techniques had no effect on the soil's pH, EC, OC, or bulk density. The 33% RDN+2 nano urea spray produced the maximum agronomic efficiency, which was statistically comparable to the 66% RDN + 1 nano urea spray. Additionally, the 33% RDN+2 nano urea spray produced a considerably greater agro physiological efficiency than the rest treatment. The 66% RDN + 1 nano urea spray had the most apparent recovery efficiency (%), which was statistically at par with the 66% RDN + 1 nano urea spray + green seeker.

Keywords: Rice, Nitrogen, nano urea, DSR, TPR.

INTRODUCTION

Rice is a vital food crop and is widely cultivated around the world, especially in Asia. India is the second-biggest producer of rice (121.4 mt) behind China and has the largest area planted to rice (43.8 m hectares). About 1.52 million hectares of rice are grown in Haryana, with yields and production of 55.14 mt and 3605 kg/ha, respectively. Currently, the main method for cultivating rice is the transplanting method (TPR). This conventional rice-growing method's excessive use of ground water led to the water table being drained and other detrimental impacts on the environment and soil quality, such as a rise in methane emissions, the development of hard pans at shallow soil depths, and a decrease in the subsurface layer's permeability.

Because transplanting requires a lot of water, labour, and energy—all of which are increasingly scarcer these days—the sustainability of the rice-production system is called into doubt. The ground water table in the northwest Indo Gangetic plains is dropping at a rate of 0.33 meters per year, according to data from NASA and the German Aerospace Centre (Rodell *et al*., 2009). The weed issue and the scarcity of reasonably priced pesticides for weed control in direct seeded rice (DSR) were the main factors in the rapid switch to PTR. The advent of dwarf rice cultivars with excellent yields that were engineered to respond to additional inputs further facilitated PTR establishment procedures (Pandey and Velasco 2005).

However, the rapid depletion of water supplies, significant wage increases, and labour shortages in the twenty-first century is forcing farmers to convert to DSR (Mortimer *et al*., 2008). DSR lowers greenhouse gas emissions and saves labour (40–45%), water (30–40%), fuel (60–70%), and other resources (Ladha *et al*., 2005). Simple planting, improved soil health, lower methane emissions, and often higher net returns in guaranteed irrigation areas are some of the other benefits of DSR (Kumar and Ladha 2011).

A Punjab farmers' fields' survey found that, in comparison to TPR, DSR conserved farmers' fields between 18 to 20% of the irrigation water and 14 person-days/ha (Bhullar *et al*., 2018). Since nitrogen (N) is an essential structural component of protein, enzymes, and chlorophyll, it ranks first among other inputs in terms of crop development and production. The best possible application of nitrogen is needed to increase yield and enhance produce quality, particularly in the contemporary intensive growing technique. An element that is necessary for all crops is nitrogen (N). Compared to other crops, cereal crops need more nitrogen to develop, grow, and yield grain (Sahrawat, 2000). Between 40 and 70 percent of nitrogen sprayed is lost to the environment (Trenkel, 2010).

Over application of nitrogen has a number of negative effects on the environment, including denitrification, the release of greenhouse gases through ammonia volatilization, groundwater pollution, and the eutrophication of aquatic bodies as a result of elevated nitrate concentrations. According to Solanki *et al.* (2015), 298 kg of CO_2 is equal to one kilograms of NOx emissions caused by volatilization. Generally prilled urea is used to fertilise rice, although the nitrogen delivered by prilled urea is less effective because it only provide 30 to 45 percent of the total nitrogen applied. Denitrification, ammonia volatilization, and leaching losses are the main causes of low N ue efficiency in rice agriculture (Hakeem *et al*., 2011). Slow-release fertilisers must be developed in order to maintain N availability throughout the crop season and control nitrification processes.

The most effective way to reduce the negative effects of uneven use of conventional chemical fertilisers on agricultural output, farmer income, the environment, and the national economy is to apply nitrogen using nanotechnology in the form of nano fertiliser (NF), which is applied based on a real-time optical sensor-corrected and guided dose of N while taking the field's temporal and spatial variability into account. Because it is smaller in size and more reactive than conventional fertiliser, nano fertiliser can reach the target site more quickly. Utilizing NF and green seeker in agriculture can help overcome the difficulties associated with applying nutrients precisely by using a methodical nutrient delivery system (Rostaman *et al*., 2021).

It is crucial to evaluate the impact of precise nitrogen management using nano urea and optical sensors when researching crop establishing techniques. With the aforementioned variables in mind, the current experiment attempts to investigate the impact of precise nitrogen control utilizing optical sensors and nano urea on the development and yield characteristics of basmati rice under various establishment techniques.

MATERIALS AND METHODS

The field experiment was carried out at the CCS HAU Research Farm, Rice Research Station, Kaul (Kaithal), Haryana, during the *Kharif* season of 2022 and 2023. With a moderate organic carbon content (0.54%), low accessible nitrogen (180 kg/ha), medium phosphorus (31 kg/ha), high potash (387 kg/ha), and a somewhat alkaline pH (8.2), the sandy clay loam soil in the field had an electrical conductivity (EC) of 0.26 dS/m. The Pusa Basmati-1121 rice variety was planted. With ten nitrogen management techniques as the subplots and two establishment methods (direct seeding and transplanting) as the main plots, the experiment used a randomised block design (RBD) factorial design that was reproduced three times.

Application of fertilizers. Phosphorus was applied at a basal dose of 30 kg P_2O_5/ha (by single super phosphate) and 25 kg $ZnSO_4$ in both DSR and TPR at the time of seeding and transplanting, respectively. Each dosage of nitrogen (as pelleted urea and nano urea) was applied to transplanted rice at 0, 21, and 42 DAT, and to DSR at 20, 40, and 60 DAS. The timing and dosage of the nitrogenous fertiliser were in line with the information provided in Table 1. One week after the third dosage was applied, the fourth dose of the green seeker-based nitrogen application for treatments 7 and 8 was applied.

Table 1: Detail of N application.

Treatments	N applied in 1^{st} dose	N applied in 2nd dose	N applied in 3rd dose	N(green seeker based) applied in 4th dose if any	Total nitrogen applied
T_1: Control	0	0	0	-	0
T_2: 100 % RDN	30 kg	30 kg	30 kg	-	90 kg
T_3: 66% RDN + 1 Nano Urea spray	30 kg	30 kg	Nano urea spray	-	60 kg
T_4: 33% RDN+ 2 Nano Urea sprays	30 kg	Nano urea	Nano urea spray	-	30 kg
T_5: 33% RDN+ 1 Nano Urea spray + Green Seeker	30 kg	Nano urea	25 kg	-	55 kg
T_6: 66% RDN + Green Seeker	30 kg	30 kg	22 kg	-	82 kg
T_7:66% RDN + 1 Nano Urea spray + Green Seeker	30 kg	30 kg	Nano urea spray	4 kg	64 kg
T_8: 33% RDN+ 2 Nano Urea sprays + Green Seeker	30 kg	Nano urea spray	Nano urea spray	17 kg	47 kg
T_9: 3 Nano Urea sprays	Nano urea spray	Nano urea spray	Nano urea spray	-	0 kg
T_{10}: 2 Nano Urea sprays + Green Seeker	Nano urea spray	Nano urea spray	45 kg	-	45 kg

The composite samples from each plot were taken at three different depths, ranging from 0 to 15 cm. Quartering the sample yielded the final weight of 500 g for the working sample. The final sample was sun-dried and then baked at 70 degrees Celsius for a full day. A wooden mortar was used to grind the dry material after it had been filtered through a 2 mm sieve.

The soil's pH was determined using an alkaline permanganate method (Subbiah and Asija 1956); EC was determined using the Conductivity Bridge Method and the glass electrode pH metre was used to determined pH of soil (Jackson, 1973). OC is determined by using Walkley and Blacks' Rapid Titration Method (Walkley and Black, 1934). Using the core sampler approach, the bulk density of the soil was ascertained in three randomly selected sections of each plot. The bulk density calculation technique was presented by Chopra and Kanwar (1991). A number of nitrogen utilisation efficiency metrics were calculated based on Dobermann's (2007) techniques.

Agronomical efficiency (AE): It can be expressed using the following formula: It is the extra grain yield that results from applying nutrients over the yield from the control per unit of nutrient applied.

$$AE = \frac{Y - Y_o}{F}$$

Y = Grain Yield of crop obtained with a given level of N applied;

Y_o = Yield obtained under control
F = Amount of N applied

Agro physiological efficiency (APE): It is the extra grain yield produced at a specific N level over the amount produced under control for each unit of excess N absorption over control.

$$AE = \frac{Y - Y_o}{U - U_o}$$

Y = Grain yield of crop obtained with a given N level;
Y_o= Yield obtained under control,
U = N uptake by grain with given N level;
U_o= N uptake by grain in control

Apparent Recovery Efficiency (ARE): It is the extra absorption of nutrients relative to control for each applied unit of nutrients. The expression for it is %.

$$ARE = \frac{U - U_o}{F}$$

U = N uptake by grain with given N level;
U_o = N uptake by grain under control
F = Amount of N applied;

Partial factor productivity of applied N: The calculation of partial factor productivity (PFP) involves dividing the total grain yield obtained by the applied nutrient. It can also be represented as kg of harvested product per kg of applied nitrogen and used to measure nitrogen utilisation efficiency.

$$PEP = \frac{\text{Yield under treatment (kg ha}^{-1})}{\text{Amount of nutrient added (kg ha}^{-1})}$$

Nitrogen harvest index (%): It is computed by following formula:

$$NHI = \frac{\text{Nitrogen uptake by grain at harvest}}{\text{Nitrogen uptake by whole plant (grain + straw) at harvest}} \times 100$$

RESULTS AND DISCUSSION

Table 2 contains information about the physiochemical characteristics of soil. After analyzing the data, it was determined that the establishment procedures had no effect on pH, EC, OC or bulk density. Following rice harvest, the physiochemical characteristics of the soil, such as pH, EC, OC, and bulk density, were not affected by precision nitrogen management.

Table 3 presents various nitrogen use efficiency and nitrogen harvest index as influenced by techniques of establishment. Following analysis of the data, it is determined that establishment procedures had no effect on different nitrogen use efficiency. Transplanted rice was found to have a considerably greater nitrogen harvest index than direct seeded rice.

Table 2: Effect of methods of establishment and precision nitrogen management on physiochemical properties of soil.

Treatments	Physiochemical property											
	pH			EC (ds/m)			OC (%)			Bulk Density (gcm^{-3})		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
Methods of establishment												
DSR.	8.2	8.1	8.2	0.26	0.26	0.26	0.55	0.56	0.56	1.41	1.41	1.41
TPR.	8.2	8.1	8.2	0.26	0.27	0.26	0.56	0.56	0.56	1.42	1.42	1.42
SE(m)±	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen management												
Control	8.1	8.2	8.2	0.26	0.27	0.27	0.55	0.56	0.55	1.41	1.42	1.41
100 % RDN	8.2	8.1	8.1	0.27	0.28	0.28	0.56	0.55	0.55	1.42	1.44	1.43
66% RDN + 1 Nano Urea spray	8.2	8.2	8.2	0.27	0.26	0.26	0.56	0.57	0.56	1.41	1.43	1.42
33% RDN+ 2 Nano Urea sprays	8.2	8.2	8.2	0.25	0.24	0.25	0.56	0.55	0.55	1.41	1.44	1.42
33% RDN+ 1 Nano Urea spray + Green Seeker	8.2	8.3	8.2	0.26	0.25	0.25	0.56	0.56	0.56	1.41	1.42	1.42
66% RDN + Green Seeker	8.2	8.1	8.1	0.27	0.26	0.26	0.56	0.56	0.56	1.41	1.44	1.43
66% RDN + 1 Nano Urea spray+ Green Seeker	8.2	8.2	8.2	0.27	0.26	0.26	0.56	0.57	0.56	1.41	1.41	1.41
33% RDN+ 2Nano Urea sprays +Green Seeker	8.2	8.3	8.3	0.27	0.27	0.27	0.57	0.56	0.56	1.41	1.42	1.41
3Nano Urea sprays	8.2	8.3	8.2	0.26	0.27	0.26	0.56	0.57	0.56	1.41	1.42	1.41
2 Nano Urea sprays + Green Seeker	8.1	8.2	8.1	0.26	0.27	0.27	0.56	0.57	0.56	1.42	1.45	1.43
SE(m)±	0.07	0.06	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Maximum agronomic efficiency was reported with 33% RDN+ 2 Nano Urea sprays in the nitrogen management treatment instance. This treatment, however, was statistically at par with the 66% RDN+ 2 nano urea spray. It was observed that 2 nano urea spray+ green seeker had the lowest agronomic efficiency. A comparable pattern was discovered in both research years. Under 33% RDN + 2 nano urea spray, there was a noticeably increased agronomic efficiency because the spray caused a direct penetration of nanoparticles into the plant system through the plant's pores, increasing rice yield per unit of N applied. These result

corroborates the findings of the Subramani *et al.* (2023); Sahu *et al.* (2022); Velmurugan *et al*. (2021).
Spraying 33% RDN+ 2 Nano Urea resulted in significantly enhanced agro-physiological efficiency. This treatment, however, was comparable to three nano urea sprays, two nano urea sprays, and green seeker. A comparable pattern was noted throughout both research years. The nitrogen harvest index was unaffected by different nitrogen management strategies.
In 2022 and 2023, the highest recovery efficiency was recorded with a 66% RDN+ 1 nano urea spray. The 66% RDN+1 nano urea spray has much higher recovery efficiency than the rest therapy. In both study years, the maximum partial factor productivity was under 33% RDN+ 2 nano urea spray, and it was significantly greater than other treatments. The nitrogen harvest index was unaffected by different nitrogen management strategies. Under various precision nitrogen management strategies, the nitrogen harvest index stayed statistically equivalent to one another.

Table 3:Nitrogen use efficiency of rice as affected by methods of establishment and precision nitrogen management in Basmati rice.

Treatments	Nitrogen use efficiency														
	Agronomic efficiency (kg grain/kg N applied)			Agro physiological efficiency (kg grain/kg N uptake)			Apparent recovery efficiency (%)			Partial factor productivity			Nitrogen harvest index		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
Methods of establishment															
DSR.	19.2	19.9	19.5	60.2	58.5	59.3	29.7	30.5	30.1	56.6	59.0	57.8	54.3	55.1	54.7
TPR.	19.2	18.9	19.0	58.2	59.0	58.6	30.2	29.0	29.6	58.2	60.5	59.3	55.5	56.0	55.7
SE(m)±	0.7	0.6	0.3	0.8	0.8	0.5	1.0	0.9	0.5	0.6	0.6	0.6	0.4	0.3	0.2
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.2	1	0.7
Nitrogen management															
Control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.7	55.9	55.3
100 % RDN	22.3	22.8	22.5	59.0	65.2	62.1	37.8	35.5	36.6	50.5	52.5	51.5	54.7	54.2	54.4
66% RDN + 1 Nano Urea spray	30.7	31.6	31.2	60.1	64.8	62.4	51.6	48.7	50.2	73.0	76.2	74.6	55.0	54.7	54.9
33% RDN+ 2 Nano Urea sprays	31.2	31.7	31.4	75.5	69.3	72.4	41.1	45.6	43.3	115.7	121.0	118.4	54.0	55.3	54.6
33% RDN+ 1 Nano Urea spray + Green Seeker	20.3	20.7	20.5	66.7	61.3	64.0	30.6	33.8	32.2	66.4	69.4	67.9	54.9	56.2	55.6
66% RDN + Green Seeker	23.6	23.6	23.6	63.6	67.7	65.6	37.5	34.9	36.2	54.6	56.3	55.4	54.4	54.2	54.3
66% RDN + 1 Nano Urea spray+ Green Seeker	30.4	30.4	30.4	62.0	68.0	65.0	49.2	44.8	47.0	70.0	72.3	71.2	54.2	53.9	54.1
33% RDN+ 2Nano Urea sprays +Green Seeker	21.0	20.3	20.6	60.5	58.5	59.5	34.4	34.7	34.5	74.9	77.3	76.1	55.3	56.4	55.8
3Nano Urea sprays	-	-	-	73.3	66.5	69.9	-	-	-	-	-	-	56.0	57.5	56.7
2 Nano Urea sprays + Green Seeker	12.3	12.8	12.6	71.3	66.4	68.9	17.3	19.3	18.3	68.7	72.4	70.5	55.7	57.2	56.5
SE(m)±	1.5	1.4	0.7	1.9	1.9	1.2	2	2	1.1	1.5	1.4	0.7	0.9	0.7	0.8
CD at 5%	4.4	4.2	2.1	5.4	5.4	3.5	6.4	5.9	3.4	4.3	4.2	2.1	NS	NS	NS

CONCLUSIONS

The physiochemical characteristics of the soil after harvest of crop were unaffected by the various precision nitrogen management techniques and establishment techniques. Different establishing techniques had no effect on the various nitrogen use efficiencies, and the nitrogen harvest index was noticeably greater under transplanted rice as compared to DSR. When using 33% RDN + 2 nano urea sprays the maximum agronomic and agro physiological efficiency was achieved in the context of nitrogen management techniques. The highest apparent recovery efficiency was achieved with 66% RDN + 2 nano urea sprays, while 33% RDN + 2 nano urea sprays produced highest partial factor productivity.

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