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Sensor based nitrogen management in direct seeded basmati rice (*Oryza sativa* L.)

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ABSTRACT

The present investigation, entitled "Sensor based nitrogen management in direct seeded basmati rice (*Oryza sativa* L.)" was conducted during the kharif season of 2025 at the Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh. The experiment was laid out in a Randomized Block Design with eight treatments replicated thrice, viz., T_1 - 50% Basal N + 25% at MT + 25% at PI through urea, T_2 - 33.3% Basal N + 33.3% at MT + 33.3% at PI through urea, T_3 - 50% Basal N + Rest through Green Seeker, T_4 - 50% Basal N + Spray of nano urea plus at MT and PI stage, T_5 - 50% Basal N + Rest through LCC, T_6 - 33.3% Basal N + Rest through Green Seeker, T_7 - 33.3% Basal N + Spray of nano urea plus at MT and PI stage, and T_8 - 33.3% Basal N + Rest through LCC. The results revealed that nitrogen management significantly influenced the growth parameters and yield-attributing characters, viz., effective tillers m^{-2} , filled grains panicle⁻¹, grain yield and test weight. The treatment T_7 recorded the highest grain yield (4500 kg ha^{-1}) and net returns (₹74,264 ha^{-1}), representing an increase of 17.1% in grain yield and ₹15,629 ha^{-1} in net returns over T_1 , respectively. Nitrogen application also improved nitrogen content and uptake and soil fertility status. The next best treatments were T_6 (33.3% Basal N + Rest through Green Seeker) and T_3 (50% Basal N + Rest through Green Seeker). In contrast, T_1 recorded the lowest values for grain yield and yield-attributing characters. The highest total nitrogen uptake (70.07 kg-ha) was recorded under T_7 , demonstrating an improvement over conventional urea application (47.45 kg-ha).

Keywords: Effective tillers, Green seeker, LCC, Maximum tillering (MT), Nano urea, Neem-coated urea, Panicle initiation (PI)

Introduction

Rice (*Oryza sativa* L.) is the most important and extensively cultivated food crop that has been referred as "Global grain" because of its use as prime staple food in about 100 countries of the world. Its cultivation is of immense importance to food security of Asia, where more than 90 % of the global rice is produced and consumed. Cereals are the most important part of our diet throughout the world and thus, play major role in our food security. Among cereals, rice has been staple food for more than 60 per cent of the world population, providing energy for about 40% of the world population where every third person on earth consumes rice every day in one form or other (Datta *et al.*, 2002) [1].

Basmati known as the "queen of India" is prized by the consumers across the world for its long grain, soft texture, extreme kernel elongation and pleasant aroma. Basmati rice is the most fragrant rice in the world with no comparison in terms of its distinctive aroma, which is caused by a chemical component known as 2-acetyl-1-pyrroline (Buttery *et al.*, 1983) [2]. Besides, there is a great diversity in non-Basmati fragrant rice cultivars in the country, which vary greatly in size, shape, colour, texture and flavour. In India basmati rice is cultivated on an area about 21.35 lakh hectares with productivity around 9.85 million tonnes at productivity level of 4.61 tonnes ha^{-1} (APEDA, 2023) [3].

Direct seeded rice (DSR) has emerged as a viable alternative to traditional transplanting methods, offering several advantages such as reduced labor, water use and greenhouse gas emissions (Jat *et al.*, 2022, Chaudhary *et al.*, 2023 and Singh *et al.*, 2024) [4]. DSR requires 30-50% less water than conventional transplanting, to make it a viable option in water-scarce regions (Sandhu *et al.*, 2021 and Chaudhary *et al.*, 2023) [5]. Labor shortage, during peak transplanting season, has always a challenge (Kumar *et al.*, 2022).). DSR eliminates need for nursery preparation, transplanting and related activities, thereby reducing Labor requirement. However, efficiency of DSR depends largely on better agronomic practices, such as choosing appropriate fertilization combinations and application timings (Ramesh *et al.*, 2017, Jat *et al.*, 2022 and Zhang and Hu, 2022) [6]. Fertilizer management has Shown a significant impact on growth, development and yield of rice (Noulas *et al.*, 2023 and Srivastav *et al.*, 2024) [7].

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Urea is the most common N source in rice production worldwide (Fageria, 2009) [8]. Tisdale *et al.* (1993) [9] also reported that the most cost-effective granular form of N is urea [CO(NH₂)₂] which is widely used as a N source because it has a high N concentration (45%) and lower relative manufacturing, handling, storage, and transportation cost. Nano

urea is a novel agri-input based on nanotechnology that gives plants nitrogen. It has a desirable particle size of roughly 20–50 nm, larger surface area (10,000 times over 1 mm urea prill), and more particles (55,000 nitrogen particles over 1 mm urea prill) than ordinary urea prill. Leaf color chart (LCC) is an affordable, user-friendly tool that helps farmers decide when and how much nitrogen fertilizer to apply. It increases rice output and N use efficiency. Farmers without literacy skills can easily use LCC to decide when to apply fertilizer N. Using the spectral properties of rice leaves was the best way to help farmers make an immediate decision on the need for top dressings of in-season fertilizer nitrogen (Singh *et al.*, 2017) [10].

Materials and methods

This chapter provides a description of the materials and methodology used in the study "Sensor based nitrogen management in direct seeded basmati rice (*Oryza sativa* L.)" The experimental site is located at a latitude of 29° 40' North and a longitude of 77° 42' East, at an altitude of 237 metres above mean sea level with a subtropical climate, Meerut lies in the central part of western Uttar Pradesh. The experimental field land was uniform in topography and possessed an efficient drainage system.

The experimental field's soil had a sandy loam texture, low levels of accessible nitrogen and organic carbon, medium levels of available phosphorus and potassium, and a reaction that was almost neutral. Pusa Basmati-1979 was sown on 20 June 2025 using a row spacing of 20 cm. The experiment was laid out in a Randomized Block Design (RBD) with 8 treatments with 3 replications. The gross plot size was 5.0 m × 3.4 m. The crop receives a total annual rainfall of 850 mm.

Results and Discussion

Yield attributing characters

Table 1. provide the information on rice yield attributes as affected by efficient nitrogen management. Improved yield contributing characteristics (number of effective tillers m⁻², Filled grains panicle⁻¹, Unfilled grains panicle⁻¹ and test weight) were observed.

Effective tillers m⁻²

It was evident from the data in Table 1 that applying nitrogen greatly enhanced the number of effective tillers m⁻² in the rice crop. The application of nitrogen, namely 33.3%

Basal N + nano urea spray at MT and PI stages (T₇) resulted in the largest number of effective tillers m⁻² (220), while T₁ (50% Basal N + 25% at MT + 25% at PI through urea) had the lowest effective tillers (185). Additionally, T₆ was considerably better than the other treatments and on par with the delivery of nitrogen @ 33.3% Basal N + Rest through Green Seeker.

Filled grains panicle⁻¹

A review of the data revealed that different nitrogen treatments had a considerable impact on the panicle⁻¹ of filled grains (Table 1). At the MT and PI stages, the administration of nitrogen (33.3% Basal N + Spray of nano urea plus at MT and PI stage) resulted in the significantly greatest number of filled grains (88) T₇. This was statistically comparable to T₆ (33.3% Basal N + Rest through Green Seeker), however T₁ (50% Basal N + 25% at MT + 25% at PI through urea) had the fewest filled grain panicle⁻¹ (70).

Unfilled grains panicle⁻¹

The data showed that different nitrogen treatments had a considerable impact on the panicle⁻¹ of unfilled grains (Table 1). T₁ (50% Basal N + 25% at MT + 25% at PI through urea) and T₇ (33.3% Basal N + Spray of nano urea plus at MT and PI stage) had the greatest (45) and lowest (32) unfilled grains panicle⁻¹, respectively.

Table 1. Effect of efficient nitrogen management on yield attributes in direct seeded basmati rice

Treatments	Yield attributes			
	Effective tillers m ⁻²	Filled grains panicle ⁻¹	Unfilled grains panicle ⁻¹	Test weight (gm)
T ₁ - 50% Basal N + 25% at MT + 25% at PI through urea	185	70	45	20.1
T ₂ - 33.3% Basal N + 33.3% at MT + 33.3% at PI through urea	190	72	43	20.3
T ₃ - 50% Basal N + Rest through Green Seeker	210	82	37	21.7
T ₄ - 50% Basal N + Spray of nano urea plus at MT and PI stage	205	80	39	21.3
T ₅ - 50% Basal N + Rest through LCC	195	75	42	20.5
T ₆ - 33.3% Basal N + Rest through Green Seeker	215	85	35	22.5
T ₇ - 33.3% Basal N + Spray of nano urea plus at MT and PI stage	220	88	32	22.8
T ₈ - 33.3% Basal N + Rest through LCC	200	78	40	20.8
S.Em±	5	3	1	0.7
C.D. (P=0.05)	15	8	4	NS

Test weight

The use of nitrogen, specifically 33.3% Basal N + nano urea spray during MT and PI stages (T₇), resulted in the noticeably highest 1000-grain weight (22.8 g). T₆, T₃, T₄, and T₈ were the next top treatments in terms of test weight. On the other hand, T₁ recorded the minimal 1000-grain weight (20.1 g), followed by T₂. Sajjad *et al.* (2024) [11] reported a similar improvement in test weight with equal split nitrogen application and Singh *et al.* (2024) found that split application of neem-coated urea enhanced yield attributes.

Yield

Table 2. provide information on rice yield as affected by efficient nitrogen management. Improved grain yield, straw yield, biological yield and harvest index were observed.

Grain yield (kg ha⁻¹)

The application of 33.3% Basal N + nano urea spray @ 4 ml l⁻¹ at MT and PI stages (T₇) produced the highest grain yield (4500 kg ha⁻¹), followed by 33.3% Basal N + Rest through Green Seeker (T₆) and significantly higher than other treatments. Farmer's practice (T₁)

had the lowest grain yield (3840 kg ha^{-1}). Although T_6 had 12.5% and 11.0% higher grain yield as compared to T_1 and T_2 respectively. Danish *et al.* (2025) [12] reported that 75% prilled urea combined with one nano urea spray recorded the highest grain yield in Basmati rice.

Straw yield (kg ha^{-1})

Table 2. provide information on straw yield as affected by various nitrogenous treatments. The highest straw production (6502 kg ha^{-1}) was seen when nitrogen @ 33.3% as Basal + nano urea was sprayed at MT and PI stages (T_7). Although the per cent increment under T_3 (50% Basal N + Rest through Green Seeker) was to the tune of 1.8% over T_1 (50% Basal N + 25% at MT + 25% at PI through urea), which registered the lowest straw yield (6120 kg ha^{-1}).

Biological yield (kg ha^{-1})

The maximum biological yield (11002 kg ha^{-1}) was recorded with 33.3% Basal N + nano urea spray applied at MT and PI stages) T_7 followed by T_6 (33.3% Basal N + Rest through Green Seeker). However, T_6 had 7.8 % and 6.2 % higher biological yield in comparison to T_1 (50% Basal N + 25% at MT + 25% at PI through urea) and T_2 (33.3% Basal N + 33.3% at MT + 33.3% at PI through urea). The lowest biological yield (9960 kg ha^{-1}) was recorded in T_1 followed by T_2 .

Harvest index (%)

Significant variation was brought about by different nitrogen management treatments in the harvest index, which is the ratio of economic output to total biological yield. The treatment that received 33.3% Basal N + nano urea spray at the MT and PI phases had the highest numerical harvest index value (40.9), which was statistically comparable to T_6 , T_3 , and T_4 . Two equal split application of N over 50 % N as basal had the lowest harvest index (38.6). Treatment T_2 and T_5 were next in the order in this regard.

Table 2. Effect of efficient nitrogen management on yield parameters in direct seeded basmati rice at various stages of crop growth

Treatments	Yield (kg ha^{-1})			Harvest index (%)
	Grain	Straw	Biological	
T - 50% Basal N + 25% at MT + 1 25% at PI through urea	3840	6120	9960	38.6
T - 33.3% Basal N + 33.3% at MT + 2 33.3% at PI through urea	3890	6150	10040	38.7
T - 50% Basal N + Rest through 3 Green Seeker	4190	6207	10397	40.3
T - 50% Basal N + Spray of nano 4 urea plus at MT and PI stage	4130	6195	10325	40.0
T - 50% Basal N + Rest through 5 LCC	3930	5944	9874	39.8
T - 33.3% Basal N + Rest through 6 Green Seeker	4320	6346	10666	40.5
T - 33.3% Basal N + Spray of nano 7 urea plus at MT and PI stage	4500	6502	11002	40.9
T - 33.3% Basal N + Rest through 8 LCC	3990	6010	10000	39.9
S.Em.±	134	200	326	2.2
C.D. ($P = 0.05$)	406	NS	986	NS

Nitrogen content and its uptake

The chemical analysis data concerning N content and its uptake by grain, straw and the total crop are presented in Table 3.

Nitrogen content in grain and straw (%)

The application of 33.3% Basal N + Spray of Nano urea plus @ 4 ml l^{-1} at MT and PI stage (T_7) resulted in significantly higher nitrogen content in grain and straw (1.42% and 0.77%, respectively). This was statistically comparable to T_6 (33.3% Basal N + Rest through Green

Seeker) and T_3 (33.3% Basal N + 33.3% at MT + 33.3% at PI through urea) than the other treatments. However, T_1 (50% Basal N + 25% at MT + 25% at PI through urea) had the lowest nitrogen concentration in grain (1.29%) and straw (0.61%). Chang *et al.* (2022) reported that controlled-release urea significantly increased the nitrogen recovery and decreased nitrogen losses, while, Li *et al.* (2018) [13] found that polymer-coated CRU enhanced nitrogen uptake and NUE. Patel *et al.* (2019) [14] also reported that split application of neem-coated urea boosted nitrogen use efficiency and nutrient uptake.

Table 3. Effect of efficient nitrogen management on nitrogen contents and its uptake in direct seeded basmati rice at various stages of crop growth

Treatments	N content (%)		N uptake (kg ha ⁻¹)		
	Grain	Straw	Grain	Straw	Total
T ₁ - 50% Basal N + 25% at MT + 25% at PI through urea	1.29	0.61	24.03	23.42	47.45
T ₂ - 33.3% Basal N + 33.3% at MT + 33.3% at PI through urea	1.30	0.62	24.74	24.12	48.86
T ₃ - 50% Basal N + Rest through Green Seeker	1.37	0.71	30.46	29.75	60.21
T ₄ - 50% Basal N + Spray of nano urea plus at MT and PI stage	1.34	0.67	28.34	27.67	56.01
T ₅ - 50% Basal N + Rest through LCC	1.31	0.64	25.79	25.15	50.94
T ₆ - 33.3% Basal N + Rest through Green Seeker	1.39	0.73	32.27	31.54	63.81
T ₇ - 33.3% Basal N + Spray of nano urea plus at MT and PI stage	1.42	0.77	35.42	34.65	70.07
T ₈ - 33.3% Basal N + Rest through LCC	1.33	0.65	26.59	25.94	52.53
S.Em±	0.04	0.02	2.72	0.91	1.9
C.D. (P=0.05)	0.13	0.7	8.23	2.76	5.8

Nitrogen uptake (kg ha⁻¹)

In comparison to the other treatments, the application of 33.3% Basal N + Spray of Nano urea plus @ 4 ml l⁻¹ at MT and PI stage (T₇) had significantly higher nitrogen uptake in grains, straw and total uptake (35.4, 34.6, and 70.07 kg ha⁻¹, respectively). This might be probably due to more accumulation of nitrogen and higher yield under T₇. This was statistically comparable to the application of nitrogen @ 33.3% Basal N + Rest through Green Seeker (T₆). However, treatment T₁ had the lowest uptake in grains (24.03 kg ha⁻¹), straw (23.42 kg ha⁻¹) and total (47.45 kg ha⁻¹) followed by T₂.

Conclusion

Based on the experimental results, it can be concluded that applying 33.3% basal N along with nano urea spray @ 4 ml l⁻¹ at MT and PI stages enhances the yield attributes, yield and total nutrient uptake in rice. The next best option is sensor based i.e., 33.3% basal N along with Green Seeker based N application.

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