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Effect of nitrogen and post-emergence herbicide on soil chemical properties in wet direct seeded rice (*Oryza sativa* L.)

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ABSTRACT

A field trial was conducted during two successive Kharif seasons in 2024 and 2025 at the Agronomy research farm of ANDUAT, Kumarganj, Ayodhya, to assess the impact of nitrogen management and combinations of post-emergence herbicides on soil chemical properties of wet direct-seeded rice. (*Oryza sativa* L.). The experiment was laid out in split-plot design and replicated thrice. The treatments consisted of three nitrogen management practices viz. N_1 : P100%K100% (basal), N100% through conventional urea (50% basal+25% at tillering+25% at PI), N_2 : P100%K100% (basal), N75% through conventional urea (50% basal+25% at tillering) + one spray nano urea at PI, N_3 : P100%K100% (basal), N50% through conventional urea (basal) + one spray nano urea at tillering + one spray nano urea at PI were kept in main plot and five weed management practices viz. W_0 : Weedy Check, W_1 : Weed free, W_2 : Chlorimuron @ 2 g a.i./ha + Metsulfuron @ 2 g a.i./ha at 25 DAS, W_3 : Bispyribac-sodium @ 25 g a.i./ha + Azimsulfuron @ 18 g a.i./ha at 25 DAS, W_4 : Bispyribac-sodium @ 25 g a.i./ha + Pyrazosulfuron @ 25 g a.i./ha at 25 DAS in sub plot. Post-harvest soil analyses indicated that N_2 , W_1 and W_3 maintained or improved available soil NPK levels as compared to initial values and untreated control. There were no significant differences in soil pH, EC and organic carbon amongst the treatments and the important soil properties were not adversely affected by the management practices tested.

Keywords: Nitrogen management, Post-emergence herbicide, NPK levels, Soil chemical properties, Wet direct-seeded rice

Introduction

An estimated 154.024 million tons of rice were produced in India in 2024-2025, an increase over 150.184 million tonnes. With 198.05 lakh tons, Uttar Pradesh topped the list of states, followed by Telangana 185.29 lakh, West Bengal 171.36 lakh, Punjab 125.33 lakh, and Andhra Pradesh 105.85 lakh. (MoA & FW, 2026). Because of their favourable agro-climatic conditions, irrigation systems, superior cultivars, and intensive crop management techniques, these states collectively contribute significantly to the country's rice production. In countries like India, rice is not just a staple food, but a segment of the culture, heritage and economy. Rice cultivation is a way of life for millions of small and marginal farmers; a tradition transmitted from generation to generation. With the world population on course to peak in 2050, the need to grow more rice is ever greater, but it is necessary with dwindling natural endowments, depleting groundwater, rising production costs and growing environmental concerns. There is never a greater need for sustainable intensification of rice-based production systems. It is a quest to feed the world but also to do it in a way that keeps the earth for the future generations. Wet direct-seeded rice (WDSR) has emerged as a promising alternative to conventional transplanted rice cultivation. In this method, pre-germinated or dry seeds are sown directly in moist or puddled soil without the need for nursery raising and transplanting. Wet direct seeding reduces labour and water requirements, lowers production costs, shortens crop duration, and enables timely sowing of succeeding crops. It also minimizes transplanting shock and reduces the drudgery associated with manual transplanting operations. Furthermore, better soil aeration under direct-seeded conditions can favour improved root development, root proliferation, and nutrient uptake. A well-developed root system plays a crucial role in anchorage, absorption of water and nutrients, and overall crop productivity. Therefore, management practices that enhance root growth are essential for achieving higher productivity in wet direct-seeded rice (Kumar *et al.*, 2017) [1]. Post-emergence herbicides provide an effective and economical approach for weed control in wet direct-seeded rice. These herbicides control weeds after emergence and reduce crop-weed competition during critical growth stages. Different post-emergence herbicides and their combinations are effective against a broad spectrum of weeds and help improve crop growth by ensuring better availability of nutrients, water, and sunlight to rice plants. Effective weed control also promotes better root growth, higher dry matter accumulation, improved yield attributes, and enhanced grain and straw yield. Among various weed management options, combinations of herbicides are often preferred because they provide wider weed control and

improve crop performance under diverse weed flora conditions (Singh *et al.*, 2016) [2]. Although several studies have been conducted separately on nitrogen management and herbicide application in rice, limited information is available regarding their combined influence on soil chemical properties under wet direct-seeded conditions. Hence, the present investigation was undertaken to evaluate the effect of nitrogen levels and post-emergence herbicides on soil properties of wet direct-seeded rice and to identify suitable management practices for enhancing productivity and sustainability of rice cultivation. Bottom of Form

Materials and methods

A field trial was carried out at the research farm of Acharya Narendra Deva University of Agriculture and Technology, located in Kumarganj, Ayodhya, over two consecutive Kharif seasons in 2024 and 2025. The experimental site (Kumarganj) is situated at a latitude of 26°47' North and a longitude of 82°12' East, with an elevation of approximately 113 meters above mean sea level in the Indo-Gangetic plains of Uttar Pradesh. The experimental field was well levelled having good irrigation and drainage facilities. The source of irrigation was tube-well. The Ayodhya district experiences a sub-humid climate, with an average annual rainfall of around 1200 mm, of which nearly 90% occurs from mid-June to the end of September. Rainfall and temperature data during the experimentation were depicted in Fig. 1. The experimental plot's soil was characterized by a silty loam texture, alkaline response, low organic carbon content, limited accessible nitrogen, and medium levels of available phosphorus and potassium. The experiment was laid out in a split plot design with three replications. In the main plot, three nitrogen management practices viz N₁: P_{100%} K_{100%} (basal), N_{100%} through conventional urea (50% basal+25% at tillering+25% at PI), N₂: P_{100%} K_{100%} (basal), N_{75%} through conventional urea (50% basal+25% at tillering) + one spray nano urea at PI and N₃: P_{100%} K_{100%} (basal), N_{50%} through conventional urea (basal) + one spray nano urea at tillering + one spray nano urea at PI. Whereas in Sub-plot weed management practices W₀: Weedy Check W₁: Weed free, W₂: Chlorimuron @ 2 g a.i./ha + Metsulfuron @ 2 g a.i./ha at 25 DAS, W₃: Bispyribac-sodium @ 25 g a.i./ha + Azimsulfuron @ 18 g a.i./ha at 25 DAS and W₄: Bispyribac-sodium @ 25 g a.i./ha + Pyrazosulfuron @ 25 g a.i./ha at 25 DAS. Pre-soaking seeds of test variety 'NDR-2065' was carried out by sowing them in rows with 20 cm distance through drum seeder in puddled field @ 60 kg/ha. The recommended quantity of fertilizers i.e. 150:80:60 kg ha⁻¹ NPK was applied according to the treatment. Nitrogen was supplied through urea and nano urea (* 4.5 kg Urea can be replaced with 50 ml Nano Fertilizer when diluted with 10 L water. Actually, we use 5 ml/L so our 500 ml, which we use for 1 acre of land, needs to be fully diluted in 100 litres of water. * 1 hectare = 2.5 acre; 1250 ml Nano Fertilizer should be mixed with 250 litres of water). Phosphorous and potassium fertilizers were supplied through SSP and MOP, respectively. The application of nitrogen fertilizer was done in three splits i.e. 50% at the time of sowing, 25% at active tillering stage and 25% at panicle initiation stage. In contrast, however, the entire phosphorus and potassium dose were applied equally as basal at the time of planting for all treatments. The stock solution of herbicides was prepared separately in a mug by mixing them in half a liter of water, followed by addition of more water up to the required volume of spray solution. The required volume of spray solution was then sprayed using a knapsack sprayer having flat fan nozzle attachment. The volume of water used for each treatment was 600 liters per hectare. The data were statistically analyzed through ANOVA using SAS version 9.3 software. A split plot design was used having three replications and treatments and plots were considered as fixed in both the years of experiment.

Results and discussion

Available nitrogen, phosphorous and potassium (kg ha⁻¹) in soil

Available nitrogen (kg/ha) in soil after harvest

The post-harvest soil accessible nitrogen concentration was strongly impacted by the various nitrogen management strategies and PoE herbicide treatments, as shown in table 1

The data showed that among the various options for nitrogen management, the application of P_{100%} K_{100%} (basal) with N_{75%} through conventional urea (50 percent basal and 25 percent at tillering) and one spray of nano urea at 5 ml/L at PI (N₂) resulted in the highest available nitrogen, with values of 189.74 kg/ha (2024) and 190.25 kg/ha (2025). Following this, the N₁ treatment was shown to be the most successful (183.68 kg/ha in 2024 and 183.95 kg/ha in 2025), whilst the N₃ treatment was found to have the lowest values (175.73 kg/ha in 2024 and 177.52 kg/ha in 2025).

Among the PoE herbicide treatments, it was discovered that hand weeding twice (W₁) was considerably superior than weedy check (168.05 kg/ha and 168.23 kg/ha) in terms of available nitrogen (190.32 kg/ha and 192.25 kg/ha in 2024 and 2025, respectively). In addition, the soil nitrogen content rose in comparison to the starting value (167.37 kg/ha in 2024; 167.89 kg/ha in 2025) when other PoE herbicide treatments were applied.

Available phosphorous (kg/ha) in soil after harvest

The nitrogen management measures and PoE herbicide treatments resulted in a considerable difference in the amount of phosphorous that was accessible in the soil after harvest.

It was discovered that the application of P_{100%} K_{100%} (basal) and N_{75%} through traditional urea (50 percent basal and 25 percent at tillering) in conjunction with one spray of nano urea at a concentration of 5 millilitres per litre at PI (N₂) generated the highest amount of accessible phosphorous among nitrogen management treatments, with 22.19 kg/ha (2024) and 22.56 kg/ha (2025) respectively. It was then followed by nitrogen (N₂), which had a value of 21.13 kg ha⁻¹ in 2024 and 21.85 kg ha⁻¹ in 2025, respectively. In the case of the N₃ treatment, the values that were found to be the lowest were 20.13 kg ha⁻¹ and 20.89 kg ha⁻¹. In PoE herbicide combinations, the greatest available phosphorous was reported in hand weeding twice (W₁) in 2024 and 2025, with 23.25 kg/ha and 23.85 kg/ha, respectively.

This was a considerable improvement over the weedy check, which had 16.23 kg/ha and 17.00 kg/ha, respectively. When compared to the original value, all of the previous herbicide treatments of PoE resulted in increases in the amount of phosphorous that was available (15.45 kg/ha in 2024; 16.75 kg/ha in 2025).

Available potassium (kg/ha) in soil after harvest

The amount of postharvest potassium that was accessible in the soil was significantly impacted by both nitrogen management schemes and PoE herbicide applications, as shown in table 4.5. When it comes to nitrogen management strategies, the application of P_{100%} K_{100%} (basal) + NK_{5%} through traditional urea (50 percent basal and 25 percent at tillering) and one spray of nano urea at 5 ml/L at PI (N₂) recorded the maximum accessible potassium level, 349.50 kg/ha (2024) and 351.25 kg/ha (2025). The subsequent treatment was N₁, which resulted in 336.80 kg/ha in 2024 and 338.21 kg/ha in 2025. On the other hand, the N₃ treatment resulted in the lowest available potassium, which was 324.00 kg/ha in 2024 and 325.58 kg/ha in 2025.

Regarding the PoE herbicide treatments, the hand weeding at two intervals (W₁) indicated the greatest available potassium (353.35 kg/ha and 354.25 kg/ha), whereas the weedy check (W₀) presented the lowest values (268.32 kg/ha in 2024 and 269.25 kg/ha in 2025). This was the case in both 2024 and 2025. In addition, the potassium content of the soil rose as compared to the starting values (262.73 kg/ha in 2024; 267.80 kg/ha in 2025) when different PoE pesticide combinations were included.

pH, electrical conductivity and organic carbon in soil after harvesting

pH of soil after harvesting

Statistical analysis showed no significant differences, which means that neither nitrogen management nor PoE herbicide applications had a significant effect on soil pH during the study period. Soil pH after harvest was only marginally affected by different nitrogen management and PoE herbicide treatments.

In all the nitrogen management practices, pH was in a narrow range. N₁ was recorded 8.53 (2024) and 8.50 (2025), N₂ was recorded 8.47 (2024) and 8.45 (2025), and N₃ was recorded 8.45 (2024) and 8.43 (2025).

Likewise, the pH values of the PoE herbicide combinations ranged from 8.46 to 8.50 (2024) and from 8.44 to 8.49 (2025), while the weedy check (W₀) had pH of 8.50 (2024) and 8.49 (2025). The initial soil pH values were 8.7 (2024) and 8.5 (2025) and decreased slightly in all treatments.

EC of soil after harvesting

Statistical analysis showed no significant differences for these parameters (C.D. ($P = 0.05$): NS), indicating that nitrogen management and PoE herbicide treatments had no significant effect on the soil electrical conductivity after harvest. The soil electrical conductivity (EC) at 25 °C measured after harvest showed little variation in response to the different nitrogen management and PoE herbicide treatments.

For nitrogen management practices, the EC was from 0.21 to 0.23 dS/m in 2024 and from 0.19 to 0.22 dS/m in 2025. The highest EC was recorded under the N₁ treatment (0.23 dS/m in 2024 and 0.22 dS/m in 2025), and the lowest was recorded under N₃ (0.21 dS/m in 2024 and 0.19 dS/m in 2025).

In the same way, the PoE herbicide treatments showed slight differences. The EC values varied from 0.21 to 0.23 dS/m in 2024 and 0.20

to 0.22 dS/m in 2025. EC values were similar for the weedy check (W₀) and other treatments. The initial EC values were 0.24 dS/m (2024) and 0.23 dS/m (2025) showing a very slight decrease across all treatments.

Organic carbon of soil after harvesting

Statistical analysis confirmed that these differences were not significant, demonstrating that neither nitrogen management nor PoE herbicide applications had a marked effect on soil organic carbon levels during the study period.

The soil organic carbon content after harvest remained relatively stable across all nitrogen management and PoE herbicide treatments (table 4.6). Among the nitrogen management treatments, organic carbon values ranged from 0.38% to 0.41% in 2024 and 0.39% to 0.44% in 2025. The N₃ treatment recorded the highest organic carbon content (0.41% in 2024, 0.44% in 2025), while N₁ showed the lowest (0.38% in 2024, 0.39% in 2025).

For PoE herbicide treatments, organic carbon values ranged from 0.37% to 0.41% in 2024 and 0.38% to 0.43% in 2025. The hand weeding twice (W₁) treatment resulted in the highest organic carbon (0.41% in 2024, 0.43% in 2025), while the weedy check (W₀) had the lowest values (0.37% in 2024, 0.38% in 2025). Initial soil organic carbon content was 0.34% (2024) and 0.37% (2025), indicating a slight increase post-harvest.

Conclusion

Based on our findings, we concluded that the application of P_{100%} K_{100%} (basal), N_{75%} through conventional urea (50% basal+25% at tillering) + one spray nano urea at PI and combined use of Bispyribac-sodium @ 25 g a.i./ha + Azimsulfuron @ 18 g a.i./ha at 25 DAS was found promising for enhancing the root growth and yield of wet direct seeded rice. Moreover, 25% urea could be replaced with nano urea.

Table 1. Available NPK (kg ha⁻¹) in soil as influenced by nitrogen management and PoE herbicides in DSR at after harvest.

Treatments	Available -N (kg ha ⁻¹)		Available -P (kg ha ⁻¹)		Available -K (kg ha ⁻¹)	
	2024	2025	2024	2025	2024	2025
Nitrogen Management						
N ₁ :P _{100%} K _{100%} (basal), N _{100%} through conventional urea (50% basal+25% at tillering+25% at PI)	183.68	183.95	21.13	21.85	336.80	338.21
N ₂ :P _{100%} K _{100%} (basal), N _{75%} through conventional urea (50% basal+25% at tillering) + one spray nano urea @ 5 ml/L at PI	189.74	190.25	22.19	22.56	349.50	351.25
N ₃ :P _{100%} K _{100%} (basal), N _{50%} through conventional urea(basal) + one spray nano urea at tillering + one spray nano urea at PI @ 5 ml/L	175.73	177.52	20.13	20.89	324.00	325.58
S. Em ±	1.89	1.82	0.88	0.79	1.93	1.99
C.D. at 5%	5.42	5.12	NS	NS	5.86	6.10
PoE Herbicides Com.						
W ₀ : Weedy Check	168.05	168.23	16.23	17.00	268.32	269.25
W ₁ : Hand weeding twice (20 and 40 DAS)	190.32	192.25	23.25	23.85	353.35	354.25
W ₂ : Chlorimuron @ 2 g a.i./ha + Metsulfuron @ 2 g a.i./ha at 25 DAS	177.45	178.65	19.52	19.97	319.22	321.20
W ₃ : Bispyribac-sodium @ 25 g a.i./ha + Azimsulfuron @ 18 g a.i./ha at 25 DAS	187.98	189.00	22.89	23.38	349.00	352.21
W ₄ : Bispyribac-sodium @ 25 g a.i./ha + Pyrazosulfuron @ 25 g a.i./ha at 25 DAS	182.50	183.24	20.54	21.00	324.75	326.25
S. Em ±	1.34	1.37	0.39	0.41	1.78	1.83
C.D. at 5%	4.14	4.26	1.29	1.35	5.48	5.65
Initial values	167.37	167.89	15.45	16.75	262.73	267.80

(continued on next page)

Table 2. pH, EC, organic carbon in soil as influenced by nitrogen management and PoE herbicides in DSR at after harvest.

Treatments	pH		EC (dSm ⁻¹ at 25 °C)		Organic carbon (%)	
	2024	2025	2024	2025	2024	2025
Nitrogen Management						
N ₁ :P ₁₀₀ %K ₁₀₀ % (basal), N ₁₀₀ % through conventional urea (50% basal+25% at tillering+25% at PI)	8.53	8.50	0.23	0.22	0.38	0.39
N ₂ :P ₁₀₀ %K ₁₀₀ % (basal), N ₇₅ % through conventional urea (50% basal+25% at tillering) + one spray nano urea @ 5 ml/L at PI	8.47	8.45	0.22	0.21	0.40	0.42
N ₃ :P ₁₀₀ %K ₁₀₀ % (basal), N ₅₀ % through conventional urea(basal) + one spray nano urea at tillering + one spray nano urea at PI @ 5 ml/L	8.45	8.43	0.21	0.19	0.41	0.44
S. Em ±	0.03	0.04	0.02	0.01	0.02	0.02
C.D. at 5%	NS	NS	NS	NS	NS	NS
PoE Herbicides Com.						
W ₀ : Weedy Check	8.50	8.49	0.23	0.22	0.37	0.38
W ₁ : Hand weeding twice (20 and 40 DAS)	8.46	8.44	0.21	0.20	0.41	0.43
W ₂ : Chlorimuron @ 2 g a.i./ha + Metsulfuron @ 2 g a.i./ha at 25 DAS	8.49	8.48	0.22	0.21	0.38	0.39
W ₃ : Bispyribac-sodium @ 25 g a.i./ha + Azimsulfuron @ 18 g a.i./ha at 25 DAS	8.47	8.45	0.21	0.20	0.40	0.42
W ₄ : Bispyribac-sodium @ 25 g a.i./ha + Pyrazosulfuron @ 25 g a.i./ha at 25 DAS	8.46	8.47	0.22	0.21	0.39	0.40
S. Em ±	0.02	0.03	0.01	0.01	0.01	0.02
C.D. at 5%	NS	NS	NS	NS	NS	NS
Initial values	8.7	8.5	0.24	0.23	0.34	0.37

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