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Effect of Nitrogen Levels and Post-Emergence Herbicide on Root Growth and Yield of Wet Direct Seeded Rice (*Oryza sativa* L.)

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ABSTRACT

A field experiment was carried out during two consecutive *Kharif* seasons of 2024 and 2025 at Agronomy research farm of ANDUAT, Kumarganj, Ayodhya, to evaluate the effect of nitrogen management and post-emergence herbicides combinations on root growth, and yield 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: $P_{100\%}$ $K_{100\%}$ (basal), $N_{100\%}$ through conventional urea (50% basal + 25% at tillering + 25% at PI), N_2: $P_{100\%}$ $K_{100\%}$ (basal), N75% through conventional urea (50% basal+25% at tillering) + one spray nano urea at PI , 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 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. Among nitrogen management practices, N_2 recorded significantly higher Root length, Root volume, Root dry weight & grain yield (48.23 & 51.21 q ha^{-1}) and straw yield (68.96 & 72.59 q ha^{-1}) during 2024 and 2025, respectively over N_1 and N_3. Among weed management practices, the application of bispyribac-sodium @ 25 g a.i./ha + azimsulfuron @ 18 g a.i./ha at 25 DAS (W_3) proved most effective among PoE herbicide combinations, recorded significantly higher, Root length, Root volume, Root dry weight and yield and it was remained statistically at par with hand weeding twice.

Keywords Nitrogen management, Root length, Root volume, Root dry weight, Post-emergence herbicide, Yield, Wet direct-seeded rice.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops in the world and serves as a staple food for more than half of the global population. In India, rice occupies a prominent position in food security, livelihood generation, and agricultural economy. Traditionally, rice is cultivated under transplanted puddled conditions, where seedlings are raised in nurseries and later transplanted into puddled fields. Although this system ensures proper crop establishment and weed suppression, it requires large quantities of water, labor, and energy. Repeated puddling also deteriorates soil physical properties, creates hardpan layers, restricts root penetration, and adversely affects the productivity of succeeding crops. In addition, continuous flooding under transplanted rice contributes to methane emission and higher water losses. Owing to increasing labor scarcity, rising production costs, and declining water resources, alternative crop establishment methods are gaining importance in rice cultivation (Devkota *et al.* 2020).

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 labor and water requirements, lowers production costs, shortens crop duration, and enables timely sowing of succeeding crops (Kumar *et al.* 2011). It also minimizes transplanting shock and reduces the drudgery associated with manual transplanting operations. Furthermore, better soil aeration under direct-seeded conditions can favor 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 (Raj and Elizabeth 2017).

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 (Raj and Elizabeth 2017).

Although several studies have been conducted separately on nitrogen management and herbicide application in rice, limited information is available regarding their combined influence on root growth and yield under wet direct-seeded conditions. Hence, the present investigation was undertaken to evaluate the effect of nitrogen levels and post-emergence herbicides on root growth and yield of wet direct-seeded rice and to identify suitable management practices for enhancing productivity and sustainability of rice cultivation.

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. 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.

Treatment details

Main plot:

A) Nitrogen management

N_1: $P_{100\%}K_{100\%}$ (basal), $N_{100\%}$ through conventional urea (50% basal+25% at tillering+25% at PI)

N_2: $P_{100\%}K_{100\%}$ (basal), $N_{75\%}$ through conventional urea (50% basal+25% at tillering) + one spray nano urea at PI.

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.

Sub-plot:

B) PoE herbicides combinations

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.

Note:

* 4.5 kg Urea can be replaced with 50 ml Nano Fertilizer when diluted with 10 L water. Actually, we mix 5 ml/L so our 500 ml which for 1 acre gets diluted fully in 100 liters water.

* For 1 hectare = 2.5-acre, 1667 ml of Nano Fertilizers mixed with 333 Liters of water is the right quantity.

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 liters of water. *1 hectare = 2.5 acre ; 1250 ml Nano Fertilizer should be mixed with 250 liters of water). Phosphorus 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

Impact of nitrogen management and PoE herbicides on root growth of WDSR

The findings indicated that root growth were strongly affected by nitrogen management strategies. (Table 1). N_2, showed significantly higher root length (24.79 & 25.56 cm), root volume (66.76 & 71.89 cc) and root dry weight (5.97 & 6.16 g plant^{-1}) than N_1 and N_3 were recorded in respectively in both years. Some earlier studies show similar results (Lync *et al.* 1995 and Lync *et al.* 2019).

The statistics clearly indicate that weed control strategies resulted in substantial variance in the growth parameters of rice. (Table 1). Maximum root growth Viz. both of which were significantly superior

Table 1. Root growth as influenced by nitrogen management and PoE herbicides.

Treatments	Root length (cm) at 90 DAS		Root volume (cc) at 90 DAS		Root dry weight ($g\ plant^{-1}$) at 90 DAS	
	2024	2025	2024	2025	2024	2025
A. Main plot						
Nitrogen Management						
N_1 : $P_{100\%}$, $K_{100\%}$ (basal), $N_{100\%}$ through conventional urea (50% basal+ 25% at tillering+25% at PI)	20.76	22.15	60.90	63.11	5.29	5.44
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	24.79	25.56	66.76	71.89	5.97	6.16
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	20.36	21.65	59.49	62.06	5.24	5.36
SEm (±)	0.49	0.30	0.48	0.50	0.08	0.05
CD (P = 0.05)	1.98	1.20	1.95	2.03	0.31	0.22
B. Sub-plot						
PoE Herbicides Com						
W_0 : Weedy Check	15.44	16.67	46.81	47.62	4.35	4.41
W_1 : Hand weeding twice (20 and 40 DAS)	26.42	27.74	71.95	76.31	6.25	6.37
W_2 : Chlorimuron @ 2 g a.i./ha + Metsulfuron @ 2 g a.i./ha at 25 DAS	19.85	20.82	58.46	61.96	5.20	5.39
W_3 : Bispyribac-sodium @ 25 g a.i./ha + Azimsulfuron @ 18 g a.i./ha at 25 DAS	25.43	26.80	69.90	74.42	6.09	6.26
W_4 : Bispyribac-sodium @ 25 g a.i./ha + Pyrazosulfuron @ 25 g a.i./ha at 25 DAS	22.72	23.56	64.80	68.13	5.60	5.83
SEm (±)	0.74	0.66	1.28	1.24	0.09	0.12
CD (P=0.05)	2.12	1.89	3.76	3.65	0.27	0.36

to the other herbicide combinations over both years. However, minimum growth was observed under the weedy check. This shows efficiently right type use of herbicide combination leads significant weed management in rice, which is at par with the works of (Lync *et al.* 1995 and Lync *et al.* 2019).

Impact of nitrogen management and PoE herbicides on yield of WDSR

Nitrogen Management had significant effect on rice yield (Table 2). Application of $P_{100\%}$ $K_{100\%}$ (basal), $N_{75\%}$ through conventional urea (50% basal+25% at tillering) + one spray nano urea at PI produced significantly grain yield (48.23 and 51.21 q ha^{-1}), straw yield (68.96 and 72.59 q ha^{-1}), biological yield (117.19 & 123.80 q ha^{-1}) than N_1 and N_3 during both the years. However, the lowest yield was recorded in N_3 (41.70 and 44.80 q ha^{-1}) but it was found at par with N_1. (42.80 and 45.77 q ha^{-1}) Increased NUE through nano urea and chlorophyll content may be the main cause of the rise in grain weight. This would result in a greater photosynthetic rate and eventually, an abundance of photosynthates available during grain growth. Similar findings have been reported by Darjee *et al.* 2023, Chen *et al.* 2022 and He *et al.* 2024.

Early tillering and/or improved LAI are the main factors that affect yield. Long panicles that eventually produced an excess of photosynthates with improved partitioning and assimilation were the main strategies to boost yield productivity under the current circumstances. In our experiment, weed free plots remained statistically comparable with the

Table 2. Yield of DSR as influenced by nitrogen management and PoE herbicides.

Treatments	Grain yield (q/ha)		Straw yield (q/ha)		Biological yield (q/ha)		Harvest Index	
	2024	2025	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)	42.80	45.77	64.45	68.69	107.24	114.46	39.81	39.90
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	48.23	51.21	68.96	72.59	117.19	123.80	41.11	41.31
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	41.70	44.82	63.57	68.02	105.27	112.85	39.45	39.54
SEm (±)	0.35	0.32	0.47	0.25	0.81	0.57	0.06	0.10
CD (P=0.05)	1.39	1.30	1.91	1.00	3.27	2.29	0.24	0.38
PoE Herbicides Com.								
W_0 : Weedy Check	30.00	32.13	45.96	49.20	75.96	81.33	39.43	39.44
W_1 : Hand weeding twice (20 and 40 DAS)	54.08	57.32	77.88	82.25	131.96	139.57	40.97	41.06
W_2 : Chlorimuron @ 2 g a.i./ha + Met-sulfuron @ 2 g a.i./ha at 25 DAS	39.71	42.98	60.80	65.56	100.51	108.54	39.45	39.53
W_3 : Bispyribac-sodium @ 25 g a.i./ha + Azimsulfuron @ 18 g a.i./ha at 25 DAS	52.99	56.27	77.51	81.48	130.50	137.76	40.60	40.85
W_4 : Bispyribac-sodium @ 25 g a.i./ha + Pyrazosulfuron @ 25 g a.i./ha at 25 DAS	44.44	47.64	66.15	70.33	110.59	117.97	40.17	40.36
SEm (±)	0.44	0.36	0.94	0.90	1.25	1.22	0.28	0.27
CD (P=0.05)	1.30	1.06	2.77	2.65	3.66	3.29	0.82	0.78

herbicide combination bispyribac-sodium and azimsulfuron plot and both had a significantly greater yield advantage over the remain PoE herbicides combinations (Table 2). Crops grown in effectively weeded plots, either weed free or with Bispyribac-sodium and Azimsulfuron, experienced luxurious growth due to the elimination of weeds from inter and intra row spaces, as well as improved aeration due to surface soil manipulation, resulting in more spaces, water, light and nutrients available for better growth and development, resulting in superior growth and yield, and thus higher grain and straw yields of crop Saha *et al.* 2021. Our results are in close conformity with earlier studies conducted by Colbach & Cordeau, 2022 ; López-Piñeiro *et al.* 2024 ; Zhang *et al.* 2023.

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.

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