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RESEARCH NOTE

Weed management and nitrogen regimes impact on weeds growth and aerobic direct-seeded rice productivity in middle Gangetic Plains of Uttar Pradesh

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ABSTRACT

Aerobic direct-seeded rice (DSR) is a resource-efficient alternative to puddled transplanted rice but its adoption is influenced by weed infestation and nitrogen (N) management factors. A field experiment was conducted in *Kharif* 2020 at Kumarganj, Ayodhya, Uttar Pradesh (U.P.), India using a split-plot design with three replications. The objective of this study was to assess the impact of weed management and nitrogen (N) levels on weeds growth and aerobic DSR productivity. The main plots comprised of three N levels, *viz.* 100%, 125%, and 150% of the recommended dose (RDN), while sub-plots included five weed management options: pre-emergence application (PE) of pyrazosulfuron 25 g/ha; sequential application of pyrazosulfuron 25 g/ha PE followed by (*fb*) post-emergence application (PoE) of bispyribac-Na 25 g/ha; hand weeding twice at 20 and 40 days after seeding (DAS); weed-free, and unweeded check. 150% RDN significantly reduced weed density and dry biomass (by 27.76%) and improved rice plant height, dry matter, yield attributes, and DSR grain yield (by 14.18%) over 100% RDN. Maximum grain and straw yield were recorded with 150% RDN with hand weeding twice. However, the highest net return and benefit cost ratio (B:C) were recorded with 150% RDN and sequential application of pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25 g/ha PoE.

Keywords: Aerobic direct-seeded rice, Bispyribac-Na, Nitrogen levels, Pyrazosulfuron, Rice, Sequential herbicides application, Weed management

Half of the world's population relies on rice as their main staple diet, forming a cornerstone of food security across Asia, including India. India ranks as the world's second-largest producer and consumer of rice after China, cultivates across approximately 47.83 million hectares, resulting in a production of around 137.83 million tonnes. However, the rice productivity is relatively low at approximately 4.32 t/ha (USDA 2025). The Indo-Gangetic Plains (IGP) adopts rice-wheat crop rotation (Ladha *et al.* 2003). Conventional rice cultivation in the Indo-Gangetic Plains and Eastern India relies predominantly on puddled transplanted rice (PTR), a system characterized by labour- and water-intensive practices such as nursery preparation, seedling uprooting, puddling and manual transplanting. Although effective in controlling early weed growth through standing water, PTR imposes significant environmental and economic burdens, particularly in regions experiencing labour shortages and declining irrigation resources (Ladha *et al.* 2009).

To address these constraints, direct-seeded rice (DSR) has emerged as a promising and resource-efficient alternative, offering advantages such as reduced water and labour input, early crop establishment and lower production costs (Kumar and Ladha 2011). The aerobic rice systems cultivated under non-puddled, well-drained conditions have demonstrated water savings of up to 73% during land preparation and 56% during the crop growth phase compared to traditional lowland rice (Yaduraju *et al.* 2021). The prominent impediment to encouraging extensive adoption of DSR is increased weed pressure, arising from the absence of standing water during early growth stages. DSR allows for the simultaneous germination of rice and weeds, resulting elevated weed pressure on crop and potential yield losses ranging 35% to 90% due to lack of efficient weed control measures (Singh *et al.* 2016). Weed management in DSR is primarily achieved with herbicides, as manual weeding is constrained by labour shortages and high costs. Employing a single herbicide usually insufficient owing to the diverse and intricate DSR weed flora. Therefore, integrating

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sequential application of both pre-emergence (PE) and post-emergence (PoE) herbicides was found to be essential for effective management (Barla *et al.* 2021)

Simultaneously, nitrogen (N) management in DSR presents unique challenges due to the aerobic soil environment, which intensifies N losses through volatilization and denitrification (Thind *et al.* 2018). Consequently, higher N application rates (150–180 kg/ha) are often required to achieve yields comparable to PTR. The N availability and utilization, weed pressure further modulates DSR system as weeds compete with rice for nutrients. Studies have revealed that poor weed control can reduce N-use efficiency by 30–50%, thereby exacerbating yield losses (Patel *et al.* 2018, Mahajan and Timsina 2011). Conversely, appropriate N fertilization enhances crop vigour, expedites canopy closure and suppresses weed emergence, suggesting a dynamic interaction between weed control and nutrient management (Kumawat *et al.* 2017).

This study was conducted with an objective to evaluate aerobic DSR performance under varying weed management and nitrogen regimes and identify effective weed management option and optimal nitrogen dosage rate to optimise DSR productivity.

This field study was laid out in the *Kharif* season of 2020 at the Agronomy Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, situated at $26^0 47'$N latitudes, $82^0 12'$E longitudes with an altitude of 126 meters above mean sea-level. The location is representative of the region's medium-land-growing zone. The experimental soil was alkaline in nature had a pH 9.1, organic carbon 0.23%, low available nitrogen (115.4 kg/ha), medium available phosphorus (15.6 kg/ha) and potassium (240 kg/ha). Split-plot design with three replications was used for the experimentation. Three-nitrogen (N) levels, *viz.* 100% recommended dose (RDN) (120 kg N, 60 kg P and 40 kg K/ha), 120% RDN and 150% RDN were in main plots. Five options of managing weeds were tested including: pre-emergence application (PE) of pyrazosulfuron at 25 g/ha, pyrazosulfuron 25 g/ha PE followed by (*fb*) post-emergence application (PoE) of bispyribac-Na (PoE) at 25 g/ha, hand-weeding twice at 20 and 40 days after seeding (DAS), weed-free (up 60 DAS) and unweeded-check in sub-plots. Rice variety 'NDR-2065' (medium duration, 120-125 days with large bold grains) was sown on 24^{th} June 2020 using manual line sowing at a depth of 2-3 cm, following basal fertilizer application. Seeds were sown in rows spaced 20 cm apart, at a rate of 20 kg/ha. Harvesting was done on November 14, 2020. Urea, diammonium phosphate and muriate of potash were used as fertilizers for N, phosphorous (P) and potash (K), respectively. Half of the N dose was applied to all the treatments, while entire dosage of P and K were applied as basal. When the crop reached its maximum tillering and panicle initiation stage the remaining N was top-dressed in two equal splits.

Herbicides were applied according to the treatment using a manually operated knapsack sprayer with a flat-fan nozzle, delivering a 600 L/ha spray volume for uniform coverage. At 20 and 40 DAS, weeds were physically pulled out in accordance with the treatment. At 60 and 90 DAS, the weed density was measured. A weedy-check and weed-free plots were maintained for comparison with herbicidal treatments. Two randomly chosen quadrats (0.50 m × 0.50 m) were randomly placed at two places in each of the plot to measure weed density and dry weight (biomass) at 60 and 90 DAS. Weeds clipped at ground level were sun-dried for 2-3 days, then oven-dried at 70°C until a constant weight was achieved to determine dry biomass. Five tagged plants in each net plot had their rice yield parameters noted and averaged. Effective tillers/m^2 were counted from two randomly selected locations in each net plot and averaged. Grain yield was measured by hand threshing the harvested crop after it had been bundled in respective plots

The data were analysed using analysis of variance (ANOVA) to evaluate statistical differences among treatments through "F" test, with conclusions noted 5% level of probability. Weed density and biomass data were transformed using a square root transformation $\sqrt{x+0.5}$ before analysis. On the basis of weed data, the weed control efficiency (WCE) and weed index (WI) were calculated using the standard formulas given by Mani *et al.* 1973 and Gill and Kumar (1969), respectively, as following:

$$\mathrm{WCE}\ (\%) = \frac{\mathrm{WDc} - \mathrm{WDt}}{\mathrm{WDc}} \times 100$$

Where, WDc: weed dry matter in unweeded control (g/m^2) and WDt: weed dry matter in treated plot (g/m^2).

$$\mathrm{WI}\ (\%) = \frac{\mathrm{X} - \mathrm{Y}}{\mathrm{X}} \times 100$$

Where, X: crop yield from weed-free (up to 60 DAS) plot and Y: crop yield from treated plot for which weed index need to be calculated.

Effect on weeds

The experimental field was dominated by *Eclipta alba* (25.06%), *Cyperus species* (23.90%), *Echinochloa* spp. (18.88%), *Paspalum maximum* (16.45%) and *Commelina benghalensis* (15.70%). Singh *et al.* (2016a), Singh *et al.* (2016) and Jaiswal and Duary (2023) also observed these weed species throughout the growth cycle of DSR.

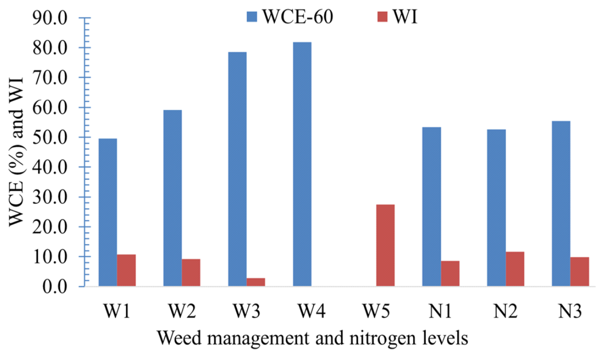
Application of higher nitrogen level *i.e.* 150% recommended N significantly lowered weed density and biomass up to 26.21 at 60 DAS when compared to the lowest amount of N *i.e.* 100% recommended N (**Table 1**). This may be attributed to enhanced crop vigour, faster canopy closure and greater competitive ability of rice plants due to efficient N uptake by crop while reducing nitrogen availability to weeds, which limit the availability of light and space for weed growth. In comparison to weedy-check, the pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25 g/ha PoE has reduced weed density by 59.88% at 60 DAS, which is comparable to manual weeding twice at 20 and 40 DAS. while Pre-emergence herbicides reduce the density of the first flush of weeds while the post-emergence herbicides control weeds that emerge later during the crucial stage of crop-weed competition (Singh *et al.* 2016a, Singh *et al.* 2023 and Patel *et al.* 2018).

The interaction between N levels and weed management practices indicated that the applying 150% recommended N combined with hand weeding twice at 20 and 40 DAS resulted in significantly reduced weed density at 60 DAS, with a reduction of 68.37%, compared to the unweeded control with 100% recommended N (**Table 1**). Among herbicidal treatments, pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na PoE with 150% recommended N, significantly reduced weed density by 46.94% at 60 DAS, relative to unweeded control. Hand weeding twice at 20 and 40 DAS and pyrazosulfuron PE *fb* bispyribac-Na PoE with 150% recommended N caused a statistically significant lowest weed biomass of 70.54%, at 60 DAS, compared to the unweeded control with 100% recommended N.

The N levels did not significantly influence weed control efficiency. However, weed index was significantly lower with 100% recommended nitrogen (8.51), followed by 150% recommended nitrogen (9.84). Among the weed management options, hand weeding twice at 20 and 40 DAS recorded the highest weed control efficiency (81.85%) and the lowest weed index (2.77) while pyrazosulfuron PE *fb* bispyribac-Na PoE, recorded weed control efficiency of 78.50% and weed index of 9.44. (**Figure 1**).

Effect on rice

Application of N level 150% of recommended N resulted in significant increase in rice plant height and dry matter accumulation (DMA) to the extent of 7.85% and 11.78% compared to 100% recommended N, respectively supporting findings of Tiwari *et al.* (2017). Among herbicide treatments, pyrazosulfuron PE *fb* bispyribac-Na PoE recorded significant increase in plant height (19.24%) and DMA (23.23%) compared to unweeded check. The combined effect of N level and weed management revealed that the significantly maximum DMA of rice found in



W1: Pyrazosulfuron 25 g/ha PE; W2: Pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25 g/ha PoE; W3: Hand weeding twice (20 and 40 DAS); W4: Weed free; W5: Weedy check; N1: 100% RDN; N2: 125% RDN; N3 = 150% RDN

Figure 1. Weed control efficiency and weed index

Table 1. Interaction effect of nitrogen levels and weed management treatments on weed density and biomass at 60 days after sowing

Treatment	Weed density (no./m^2)			Weed dry biomass (g/m^2)		
	100% RDN	125% RDN	150% RDN	100% RDN	125% RDN	150% RDN
Pyrazosulfuron 25 g/ha PE	7.27(52.40)	7.06(49.40)	6.25(40.20)	6.09(36.68)	5.92(34.58)	5.35(28.14)
Pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25 g/ha PoE	6.48(41.60)	6.19(38.00)	5.81(33.30)	5.44(29.12)	5.20(26.60)	4.87(23.31)
Hand weeding twice (20 and 40 DAS)	5.03(24.80)	4.74(22.00)	4.34(18.40)	4.22(17.36)	3.99(15.40)	3.66(12.88)
Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
Weedy check	10.60(112.00)	9.54(91.00)	8.88(78.40)	8.87(78.40)	8.00(63.70)	7.43(54.88)
LSD (p=0.05)		0.586			0.435	

*Data in parentheses are original value which were transformed to $\sqrt{x+0.5}$ for analysis
PE = pre-emergence application; PoE = post-emergence application; *fb* = followed by; RDN = recommended dose of nitrogen

Table 2. Effect of nitrogen levels and weed management treatments on rice plant height, yield attributes, yields and economics of direct-seeded rice

Treatment	Plant height (cm)	Effective tillers (no./m²)	Panicle length (cm)	Grains/ panicle (no./ panicle)	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Gross returns (₹)	Net returns (₹)	B:C ratio
Weed management										
Pyrazosulfuron 25 g/ha PE	108.67	325.20	21.53	74.52	22.18	5.38	8.25	259751	190263	2.74
Pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25 g/ha PoE	112.93	341.73	22.90	75.24	22.23	5.46	8.74	263028	193440	2.78
Hand weeding twice (20 and 40 DAS)	115.96	343.57	23.47	76.53	22.25	5.86	8.88	270869	184106	2.12
Weed free	116.33	342.50	23.97	78.84	22.29	6.02	9.12	274830	181943	1.96
Weedy check	91.20	181.80	18.43	71.28	22.13	4.36	6.74	235358	166870	2.44
LSD (p=0.05)	2.18	15.88	1.20	4.24	1.66	0.15	0.25	16014	15449	0.43
Nitrogen Levels										
100% RDN	103.44	277.88	20.34	73.24	22.19	5.036	7.69	251175	174159	2.30
125% RDN	111.36	308.70	22.82	76.06	22.23	5.50	8.61	262950	185506	2.44
150% RDN	112.25	334.30	23.02	76.55	22.24	5.74	8.74	268177	190308	2.48
LSD (p=0.05)	2.35	21.36	1.43	3.01	1.25	0.10	0.18	21180	14936	0.26
Interaction (W × N)										
LSD (p=0.05)	NS	37.00	NS	NS	NS	0.61	0.31	NS	NS	NS

PE = pre-emergence application; PoE = post-emergence application; *fb* = followed by; RDN = recommended dose of nitrogen

Table 3. Interaction effect of nitrogen levels and weed management options on rice dry matter accumulation, grain yield and straw yield of direct-seeded rice (DSR)

Treatment	100% RDN	125% RDN	150% RDN	LSD (p=0.5)
Rice dry matter accumulation (g/m²)				
Pyrazosulfuron 25 g/ha PE	1243.0	1421.0	1424.5	
Pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25g/ha PoE	1321.5	1503.0	1513.0	
Hand weeding twice (20 and 40 DAS)	1342.0	1534.0	1546.0	157.45
Weed free	1383.0	1574.0	1586.0	
Weedy-check	1068.0	1125.0	1137.0	
Rice grain yield (t/ha)				
Pyrazosulfuron 25 g/ha PE	4.90	5.58	5.67	
Pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25g/ha PoE	5.22	5.22	5.95	
Hand weeding twice (20 and 40 DAS)	5.33	6.03	6.21	0.18
Weed free	5.50	6.21	6.37	
Weedy-check	4.19	4.38	4.50	
Rice straw yield (t/ha)				
Pyrazosulfuron 25 g/ha PE	7.53	8.60	8.61	
Pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25g/ha PoE	8.00	9.08	9.14	
Hand weeding twice (20 and 40 DAS)	8.09	9.21	9.35	0.30
Weed free	8.33	9.48	9.55	
Weedy-check	6.49	6.67	7.07	

PE = pre-emergence application; PoE = post-emergence application; *fb* = followed by; RDN = recommended dose of nitrogen

application of 150% recommended N along with pyrazosulfuron *fb* bispyribac-Na up to 29.41% as compared to 100% recommended N under weedy-check plot (**Table 2** and **3**).

Significantly higher effective tillers, panicle length, grains per panicle, grain yield and straw yield were recorded by 150% of recommended N amongst N levels tested and by hand weeding twice and pyrazosulfuron *fb* bispyribac-Na among weed management treatments (**Table 2**). The findings are consistent with the results reported by Joshi *et al.* (2015), Ahmad *et al.* (2016) and Patel *et al.* (2018).

Interaction between N levels and weed management options indicated that application of 150% recommended N along with hand weeding twice at 20 and 40 DAS resulted in significantly higher grain and straw yield followed by application of pyrazosulfuron *fb* bispyribac-Na (**Table 3**).

Economics

The maximum gross return (₹ 268177/ha), net return (₹ 190308/ha) and B-C ratio (2.48) was recorded in 150% recommended N among nutrient management. Among weed management options, hand weeding (at 20 and 40 DAS) resulted highest grass return (₹ 270869) but net return (₹ 193440) and B-C ratio (2.78) was observed in sequential application of pyrazosulfuron PE *fb* bispyribac-Na PoE (**Table 2**).

Conclusion

Based on one year experiment, it can be concluded that, the highest grain yield and net returns can be obtained with the combination of 150% recommended nitrogen with sequential application of pyrazosulfuron 25 g/ha PE *fb* bispyribac-Na 25 g/ha PoE in aerobic direct-seeded rice.

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