Indian Journal of Weed Science (2025) **57**(3): 271–276
http://dx.doi.org/10.5958/0974-8164.2025.00047.9

RESEARCH ARTICLE

Bio-efficacy of carfentrazone-ethyl against broad-leaved weeds and its effect on direct-seeded rice productivity and nutrient uptake

Rajib Kundu, Takbir Ali*, Chandan De, Prabaha Maity, Koushik Brahmachari, Pijush SoMondal and Ratneswar Poddar

Received: 11 June 2025 | Revised: 21 August 2025 | Accepted: 25 August 2025

ABSTRACT

Farmers are preferring direct-seeded rice (DSR) than traditional transplanted rice cultivation practices due to water scarcity and agricultural labors shortage. However, weeds are a major challenge in DSR production systems. A field experiment was conducted at the Research farm of Bidhan Chandra Krishi Vishwavidyalaya, West Bengal, India ((22°97' N, 88°44' E, and 9.75 m above MSL) during *Kharif* seasons of 2022 and 2023 to evaluate the efficacy of varying doses of carfentrazone-ethyl in comparison with oxyfluorfen and hand weeding on diversified weed flora and assess their effect on growth, nutrient uptake and yield of direct-seeded rice for identifying a suitable herbicide and its optimum dose for sustainable direct-seeded rice production. There were seven treatments, *viz.* four doses of carfentrazone-ethyl 40% DF (carfentrazone-ethyl) 15, 20, 25 and 30 g/ha; oxyfluorfen 23.5% EC (oxyfluorfen) 240 g/ha; hand weeding twice at 20 and 40 days after seeding (DAS) and weedy check. A randomized complete block design replicated thrice was used. Among the tested herbicides, carfentrazone-ethyl 30 g/ha effectively reduced the total weed density by 55.08% and 53.83% at 30 and 45 days after seeding (DAS), respectively and biomass of broad-leaved weeds and annual sedges by 81.22% and 77.31% at 30 and 45 DAS, respectively, compared to control. The carfentrazone-ethyl 30 g/ha recorded highest rice grain yield too and may be considered as the best treatment for managing weeds, particularly when the broad-leaved weeds and sedges are predominant, in direct-seeded rice.

Keywords: Carfentrazone-ethyl, Direct-seeded rice, Oxyfluorfen, Soil Nutrient uptake, Weed management

INTRODUCTION

Rice (*Oryza sativa* L.) serves as the primary food source for nearly 60% of India's population (Biswas *et al.* 2019), with West Bengal being the leading producer (Directorate of Agriculture 2018, Jambulkar 2023). However, sustaining and enhancing rice productivity remains a challenge, as a 50–60% increase in production will be required by 2025 to meet population-driven demand (Banerjee *et al.* 2018, Rao 2022). The conventional method of rice cultivation involving transplanted rice after puddling is becoming increasingly unsustainable due to its negative impact on soil structure, high water and labour requirements and the formation of hard pans that impede the establishment of subsequent crops (Poddar *et al.* 2014, Rao *et al.* 2017). In addition, the declining groundwater table caused by excessive pumping during peak summer, combined with delayed monsoon onset, further hampers timely transplanting (Lampayan *et al.* 2015). This impacts of rice growth and yield with poor tiller formation, a shortened vegetative period and decrease dry matter accumulation. In this context, direct-seeded rice (DSR) has emerged as a promising alternative, offering advantages such as reduced labour and water use, earlier maturity, mechanization compatibility and enhanced water-use efficiency (Chauhan *et al.* 2012, Yaduraju *et al.* 2021). However, the major constraint in DSR is effective weed management, as the absence of standing water during crop establishment leads to rapid weed emergence and intense crop-weed competition (Singh *et al.* 2009, Rao *et al.* 2020, Rao and Chandrasena 2024). Therefore, a successful weed management in DSR requires a strategic approach considering weed type, land preparation and herbicide efficacy (Rao *et al.* 2007). As manual weeding is time-consuming and costly, herbicide use is a more practical alternative (Jana *et al.* 2020, Yaduraju *et al.* 2021). However, the development and identification of alternative herbicides have become increasingly important to minimize the risk of herbicide-resistant weed biotypes and to maintain high rice yields under direct-seeded conditions. While many pre-emergence herbicides are available in the market for controlling

Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur Nadia, West Bengal 741252, India

* Corresponding author email: takbirali123@gmail.com

weeds, the need for post-emergence herbicide is often realized to combat the weeds emerged during later stages of crop growth (Kundu *et al.* 2020). Carfentrazone-ethyl is a post-emergent, broad-leaved weeds killer, contact, non-residual, translocated herbicide belongs to aryl triazolinone family has been found effective (Shinde *et al.* 2018) by inhibiting activity of protoporphyrinogen oxidase in chlorophyll biosynthetic pathway (Witkowski and Halling 1989). Oxyfluorfen is also a selective post-emergence herbicide that controls weed flora (Poddar *et al.* 2014). This experiment was conducted to evaluate the efficacy of varying doses of carfentrazone-ethyl in comparison with oxyfluorfen and hand weeding on diversified weed flora, and assess their effect on growth, nutrient uptake and yield of direct-seeded rice, for identifying a suitable herbicide and its optimum dose for sustainable direct- seeded rice production in new alluvial zone of West Bengal.

MATERIALS AND METHODS

The field experiment was conducted under subtropical climate during *Kharif* 2022 and 2023 at the research farm of Bidhan Chandra Krishi Vishwavidyalaya ((22°97' N, 88°44' E, and 9.75 m above MSL), West Bengal. The soil was sandy loam containing 53.27% sand, 24.88% silt and 21.85% with a pH of 7.21 and electrical conductivity of 0.18 ds/m. It contained 0.65% organic C, 190.6 kg available N/ha, 20.53 kg available P/ha and 156.3 kg available K/ha. Weekly maximum and minimum temperatures ranged between 29.6 to 36.1°C and 11.9 and 26.9 °C during 2022 and 2023 respectively. Maximum relative humidity ranged from 89 to 94.6% in 2022 and 85.5 to 93.5% in 2023. The annual rainfall during the experimental period was 1450 and 1500 mm in 2022 and 2023, respectively. The experiment was laid out in randomized block design and replicated thrice with each plot area of 25 m^2 (5.0 x 5.0 m). The tested treatments were: carfentrazone-ethyl 40% DF (carfentrazone-ethyl) at 15, 20, 25 and 30 g/ha; oxyfluorfen 23.5% EC (oxyfluorfen) 240 g/ha; weedy check and hand weeding twice at 20 and 40 days after seeding (DAS). The amount of the herbicides was calculated as per treatments on the basis of gross plot area. Herbicides were applied as aqueous solutions at 500 L/ha using a knapsack sprayer fitted with a WFN 040 flood jet nozzle, uniformly across plots as per treatments. Post-emergence application (PoE) of carfentrazone-ethyl was applied at 15 DAS and pre-emergence application (PE) of oxyfluorfen at 3 DAS, as per the treatments dose. Since herbicides efficacy on broad-leaved weeds (BLW) and sedges was being tested, grasses were uprooted whenever they appeared in the experimental plots. Rice (*cv.* IET 4786) seeds were soaked, treated with *Trichoderma viride* (4 g/kg), shade-dried and sown at 20 × 15 cm spacing on 4th and 7th February (2022 and 2023); recommended FYM and fertilizers were applied, crops irrigated as needed and harvested on 4th and 9th June, with grain yield recorded at 15% moisture content.

For collection of data on weed parameters, four permanent quadrats (0.5 × 0.5 m) per plot were used to record weed density and biomass at 30 and 45 days after seeding (DAS); weeds were counted, washed, sun-dried, oven-dried at 70°C for 48 h and weighed. Different weed indices were worked out by using following equations (Banerjee *et al.* 2019, Kundu *et al.* 2020) respectively.

$$WCE = \frac{WDM_C - WDM_T}{WDM_C} \times 100 \ldots\ldots \text{(i)}$$

Where, WCE is weed control efficiency; WDM_c is the weed dry matter weight (g/m^2) in control plot; WDM_T is the weed dry matter weight (g/m^2) in treated plot.

$$Weed\ Infestation = \frac{Total\ number\ of\ weeds\ in\ unit\ area}{Total\ number\ of\ weeds\ and\ crop\ plants\ in\ the\ same\ area} \times 100 \ldots\ldots \text{(ii)}$$

$$TEI = \frac{Y_T - Y_C}{Y_T} \times \frac{WDM_C}{WDM_T} \ldots\ldots \text{(iii)}$$

Where TEI is treatment efficiency index; Y_T is crop yield from the treated plot; Y_C is crop yield from the control plot.

$$WI = \frac{Y_f - Y_t}{Y_f} \times 100 \ldots\ldots \text{(iv)}$$

Where WI is weed index; Y_f is yield from weed free plot; Y_t is yield from treated plot.

$$CRI = \frac{CDM_t}{CDM_c} \times \frac{WDM_c}{WDM_t} \ldots\ldots \text{(v)}$$

Where CRI is crop resistance index; CDM_t is crop dry matter (g/m^2) in treated plot; CDM_c is crop dry matter (g/m^2) in control plot.

$$HI = \frac{Economic\ yield}{Biological\ yield} \ldots\ldots \text{(vi)}$$

Where, HI is harvest index

Initial soil samples were air-dried, sieved (2 mm) and analysed for texture (textural triangle), mechanical composition (hydrometer method), pH and EC (1:2.5 soil: water, Jackson, 1967), available N (hot alkaline $KMnO_4$), P (0.5 M $NaHCO_3$, UV-VIS spectrophotometer) and K (neutral ammonium acetate extraction, flame photometry). Aboveground weed and crop samples were oven-dried (60 ± 5 °C), ground (0.5 mm), acid-digested and analysed for N, P and K content; nutrient uptake was computed on a hectare basis. The benefit-cost ratio (B:C) was calculated by dividing the gross income by the cost of cultivation. All the collected data was subjected to analysis of variance (ANOVA) according to the techniques define for simple randomized complete block design (RCBD) as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Weed growth

The experimental plots were infested with diversified weed flora and amongst them broad-leaved weeds (BLW) were the most dominating, followed by sedges and grasses, regardless of the dates of observations. The lowest sedge and broad-leaved weed density and biomass were recorded with hand weeding twice at 20 and 40 DAS, while the highest were observed in the untreated weedy check. Among the herbicides carfentrazone-ethyl 30 g/ha resulted in lowest weed density and biomass of *Ludwigia parviflora* at 30 and 45 DAS, respectively, which was statistically at par with the carfentrazone-ethyl 25 g/ha. The similar trend was observed with other broad-leaved weed species also (**Table 1** and **2**). The same treatment significantly (p≥0.05) reduced the density and biomass of *Cyperus iria* at both 30 and 45 DAS (**Table 1** and **2**). At 30 DAS, the lowest total weed density was recorded with the highest dose of carfentrazone-ethyl, which was statistically similar to the 25 g/ha. At 45 DAS, carfentrazone-ethyl 25 g/ha was significantly superior to all other herbicidal treatments. Furthermore, total weed biomass (broad-leaved weeds and sedges) was markedly reduced with carfentrazone-ethyl at 30 g/ha PoE with a reduction of 81.22% and 77.31% at 30 and 45 DAS, respectively compared to the control. This emphasizes the importance of post-emergence herbicides usage for weed control in direct-seeded rice, as it provides broad spectrum weed control and may safeguards against herbicide resistance. These findings are in conformity with the findings of Shinde *et al.* (2018) who observed lower weed density and biomass with carfentrazone-ethyl compared to other weed management treatments.

Weed control efficiency

Hand weeding twice at 20 and 40 DAT was the most efficient with higher weed control efficiency (**Table 3**) in managing broad-leaved weeds and *Cyperus* spp., at all the growth stages of direct-seeded rice. *Cyperus* spp., a predominant sedge in rice field was most efficiently (> 70%) managed by carfentrazone-ethyl 30 g/ha and was statistically similar with carfentrazone ethyl 25 g/ha. The lowest weed control efficiency was recorded with weedy check as no weed control measures were taken. Carfentrazone-ethyl 15, 20, 25 and 30 g/ha recorded varying levels of efficacy in controlling total broad-leaved weeds. The WCE for total BLW with carfentrazone-ethyl increased with increased dose and carfentrazone-ethyl 30 g/ha dose exhibited the highest efficacy (81.60% at 30 DAS and 70.44% at 45 DAS), which was statistically comparable with

Table 1. Effect of weed management treatments on weed density (no./m²) at 30 and 45 DAS (pooled data of two years) in direct-seeded rice

Treatment	*Ludwigia parviflora*		*Digera arvenses*		*Phyllanthus niruri*		*Spilanthes paniculata*		*Eclipta alba*		*Cyperus* spp.	
	30	45	30	45	30	45	30	45	30	45	30	45
Carfentrazone-ethyl PoE 15 g/ha	1.68 (2.33)	2.33 (4.93)	1.60 (2.06)	2.18 (4.29)	1.99 (3.48)	2.25 (4.57)	1.42 (1.53)	1.77 (2.65)	1.97 (3.89)	2.21 (4.39)	2.58 (6.18)	3.19 (9.69)
Carfentrazone-ethyl PoE 20 g/ha	1.63 (2.17)	2.21 (4.38)	1.57 (1.95)	2.06 (3.75)	1.92 (3.17)	2.13 (4.05)	1.33 (1.27)	1.57 (1.96)	1.82 (2.81)	2.16 (4.17)	2.43 (5.37)	3.09 (9.04)
Carfentrazone-ethyl PoE 25 g/ha	1.55 (1.89)	2.09 (3.86)	1.46 (1.63)	2.03 (3.63)	1.83 (2.85)	2.09 (3.87)	1.20 (0.95)	1.30 (1.19)	1.74 (2.54)	2.09 (3.86)	2.33 (4.91)	2.93 (8.07)
Carfentrazone-ethyl PoE 30 g/ha	1.52 (1.84)	2.04 (3.67)	1.44 (1.58)	2.01 (3.55)	1.80 (3.11)	2.01 (3.57)	1.14 (0.81)	1.25 (1.08)	1.72 (2.48)	2.00 (3.53)	2.25 (4.57)	2.91 (7.99)
Oxyfluorfen PE 240 g/ha	2.16 (4.16)	3.26 (10.10)	2.05 (3.71)	2.80 (7.35)	2.40 (5.24)	3.13 (9.28)	1.84 (2.87)	2.41 (5.33)	2.16 (4.17)	3.14 (9.34)	4.47 (19.47)	5.91 (34.38)
Control: weedy check	3.13 (9.27)	3.92 (14.83)	2.75 (7.09)	3.55 (12.08)	3.62 (12.61)	3.82 (14.09)	2.50 (5.77)	3.12 (9.23)	3.24 (10.03)	3.85 (14.33)	5.25 (27.09)	6.73 (44.83)
Hand weeding twice 20 and 40 DAS	1.20 (0.95)	1.13 (0.78)	1.28 (1.13)	1.23 (1.01)	1.21 (0.97)	1.32 (1.24)	0.94 (0.39)	0.94 (0.39)	1.28 (1.15)	1.45 (1.61)	1.76 (2.61)	1.84 (2.87)
LSD (p=0.05)	0.072	0.107	0.066	0.133	0.086	0.090	0.055	0.074	0.079	0.095	0.124	0.158

Values in the parentheses are original value and values outside parentheses are square root transformed {"(X+0.5)} values**;** *DAS = days after seeding; PoE = post-emergence application; PE = pre-emergence application carfentrazone-ethyl 25 g/ha. This indicates a dose-dependent response in controlling broad-leaved weeds as reported by Punia *et al.* (2018) and Singh *et al.* (2013).

Weed indices

The weed infestation index represents the percentage of weeds in the combined population of weeds and crop plants. The treatment efficiency index (TEI) indicates the weed killing potential of a treatment and its phytotoxicity on the crop. Carfentrazone-ethyl 30 g/ha recorded the lowest infestation index (22.17); lowest weed index (6.32) and maximum treatment efficiency (1.48) which demonstrated its superior efficiency against infested weed flora (BLW and annual sedges) in DSR. A similar trend was also observed for crop resistance index. Raj *et al.* (2013) also reported superiority of carfentrazone-ethyl over other herbicides in DSR in terms of different weed indices.

Rice yield and yield attributes

An increase in rice yield of 17.37% to 67.38% over the weedy control was observed with weed management treatments tested (**Table 4**). Among the herbicide treatments, carfentrazone-ethyl 30 g/ha recorded the highest grain yield (3.83 t/ha) which did not differ significantly from weed free (3.95 t/ha), followed by carfentrazone-ethyl 25 g/ha (3.67 t/ha). On the contrary, the minimum grain yield was

Table 2. Effect of weed management treatments on weed biomass (g/m^2) at 30 and 45 DAS in direct-seeded rice (pooled data of 2 years)

Treatment	*Ludwigia parviflora*		*Digera arvenses*		*Phyllanthus niruri*		*Spilanthes paniculata*		*Eclipta alba*		*Cyperus* spp.	
	30	45	30	45	30	45	30	45	30	45	30	45
Carfentrazone-ethyl PoE 15 g/ha	1.98	3.68	1.74	4.69	2.47	4.43	1.82	3.58	2.69	4.99	2.84	8.36
Carfentrazone-ethyl PoE 20 g/ha	1.59	3.29	1.55	4.05	1.89	3.75	1.33	2.75	1.95	4.43	2.47	7.99
Carfentrazone-ethyl PoE 25 g/ha	1.47	3.11	1.29	3.87	1.73	2.95	1.21	2.41	1.77	3.81	2.31	7.45
Carfentrazone-ethyl PoE 30 g/ha	1.36	3.08	1.28	3.79	1.72	2.90	1.17	2.35	1.69	3.71	2.23	7.37
Oxyfluorfen PE 240 g/ha	2.33	4.93	2.27	5.47	2.65	5.63	1.74	4.26	3.15	7.53	3.77	10.55
Control: weedy check	7.47	13.97	8.03	15.79	10.41	15.52	4.81	8.29	8.59	16.33	9.59	25.53
Hand weeding twice 20 and 40 DAS	0.116	0.47	0.31	0.53	0.21	0.72	0.10	0.45	0.60	1.55	1.37	2.93
LSD (p=0.05)	0.154	0.287	0.162	0.328	0.213	0.323	0.105	0.182	0.179	0.337	0.197	0.539

*DAS = days after seeding; PoE = post-emergence application; PE = pre-emergence application

Table 3. Effect of weed management treatments on weed control efficiency (WCE), weed infestation index (WII), treatment efficiency index (TEI), weed index (WI), crop resistance index (CRI) in direct-seeded rice (pooled data of 2 years)

Treatment	WCE (%)				WII		TEI	WI	CRI
	Total BLW		*Cyperus* spp.						
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS			
Carfentrazone-ethyl PoE 15 g/ha	65.49	60.10	70.39	66.08	24.84	29.06	0.74	22.11	3.53
Carfentrazone-ethyl PoE 20 g/ha	78.82	65.89	74.24	68.51	22.41	27.99	1.09	14.32	4.14
Carfentrazone-ethyl PoE 25 g/ha	80.96	69.85	75.91	70.82	22.27	25.91	1.44	7.08	4.20
Carfentrazone-ethyl PoE 30 g/ha	81.60	70.44	76.74	71.13	22.17	25.89	1.48	6.32	4.40
Oxyfluorfen PE 240 g/ha	69.06	48.06	60.69	58.68	30.72	37.10	0.36	29.87	2.60
Control: weedy check	0	0	0	0	37.60	42.36	0.00	40.25	1.03
Hand weeding twice 20 and 40 DAS	96.56	93.05	85.71	88.52	17.97	18.43	5.77	0.00	16.09
LSD (p=0.05)	2.68	2.39	2.52	2.40	-	-	-	-	-

*DAS = days after seeding; PoE = post-emergence application; PE = pre-emergence application; BLW = broad-leaved weeds

Table 4. Effect of weed management treatments on direct-seeded rice grain and straw yield and economic analysis (pooled data of 2 years)

Treatment	Yield (t/ha)				Harvest index (%)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
	Grain			Straw				
	Year I	Year II	Pooled					
Carfentrazone-ethyl PoE 15 g/ha	3.09	3.05	3.07	4.26	41.88	73278	29864	1.69
Carfentrazone-ethyl PoE 20 g/ha	3.30	3.46	3.38	4.65	42.09	80577	37058	1.85
Carfentrazone-ethyl PoE 25 g/ha	3.59	3.75	3.67	5.23	42.27	87943	44199	2.01
Carfentrazone-ethyl PoE 30 g/ha	3.77	3.89	3.83	5.06	42.23	90782	46873	2.07
Oxyfluorfen PE 240 g/ha	2.75	2.79	2.77	3.92	41.40	66308	21939	1.49
Control: weedy check	2.37	2.35	2.36	3.30	41.69	56394	14459	1.34
Hand weeding twice 20 and 40 DAS	3.88	4.02	3.95	5.37	42.38	94005	42230	1.82
LSD (p=0.05)	0.11	0.12	0.12	0.16	-	-	-	-

*DAS = days after seeding; PoE = post-emergence application; PE = pre-emergence application

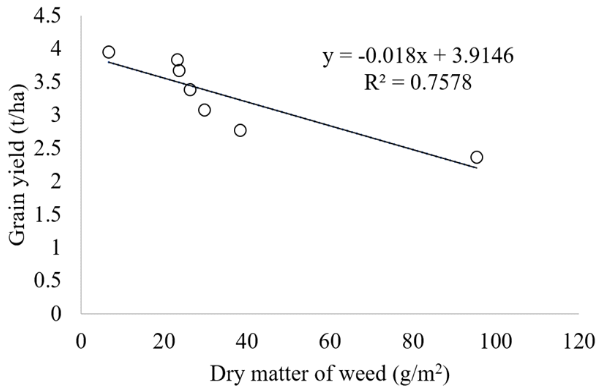

Figure 1. Relationship between weed dry matter accumulation and grain yield

observed with untreated control (2.36 t/ha) with significant DSR yield reduction of 67%. A similar trend was observed for straw yield and harvest index. This indicates that herbicide application significantly improved both grain and straw yields with a marked improvement in the harvest index over the untreated control. The higher yield of rice in effective treatments might be ascribed to effective suppression of weeds during growing phases and also utilization of more resources under lesser weeds condition (Poddar *et al.* 2014). There was a negative correlation (R^2=0.757) have been found between weed dry matter at 45 DAS and rice grain yield (**Figure 1**) indicating that it is essential to control weeds effectively as reported by Shinde *et al.* (2018), Patel *et al.* (2023) and *Singh et al.* (2013).

Nutrient uptake by rice

Plant nutrient uptake by direct-seeded rice was inversely proportional to nutrient uptake by weeds. All weed control treatments recorded significantly higher NPK uptake than weedy check at 45 DAS (**Figure 2**). Hand weeding twice at 20 and 40 DAS and carfentrazone-ethyl 30 g/ha recorded higher NPK uptake by DSR. This could be attributed to better weed control achieved by these treatments. The lowest NPK uptake in the weedy check might be due to intense crop-weed competition as observed by Chakraborti *et al.* (2017).

Nutrient removal by weeds

The uptake of N, P and K by weeds followed the pattern of weed biomass as recorded in different treatments with least in hand weeded twice, while the maximum removal of major nutrients occurred in the weedy check (**Figure 2**). Due to its effective control, carfentrazone-ethyl 30 g/ha resulted in least removal of nitrogen, phosphorus and potassium by weeds (5.58, 1.24 and 5.45 kg/ha respectively) due to its effective control of predominant BLW and sedges confirming Jaiswal *et al.* (2023).

Phytotoxicity of herbicides

The rice plants were carefully examined for phytotoxicity symptoms at 1, 3, 5, 7 and 10 days after herbicide application and no phytotoxicity was observed.

Economics

Among all weed control treatments tested, the highest net return and benefit-cost ratio were recorded with carfentrazone-ethyl 30 g/ha followed by carfentrazone-ethyl 25 g/ha. Although hand weeding improved yields and gross income, the

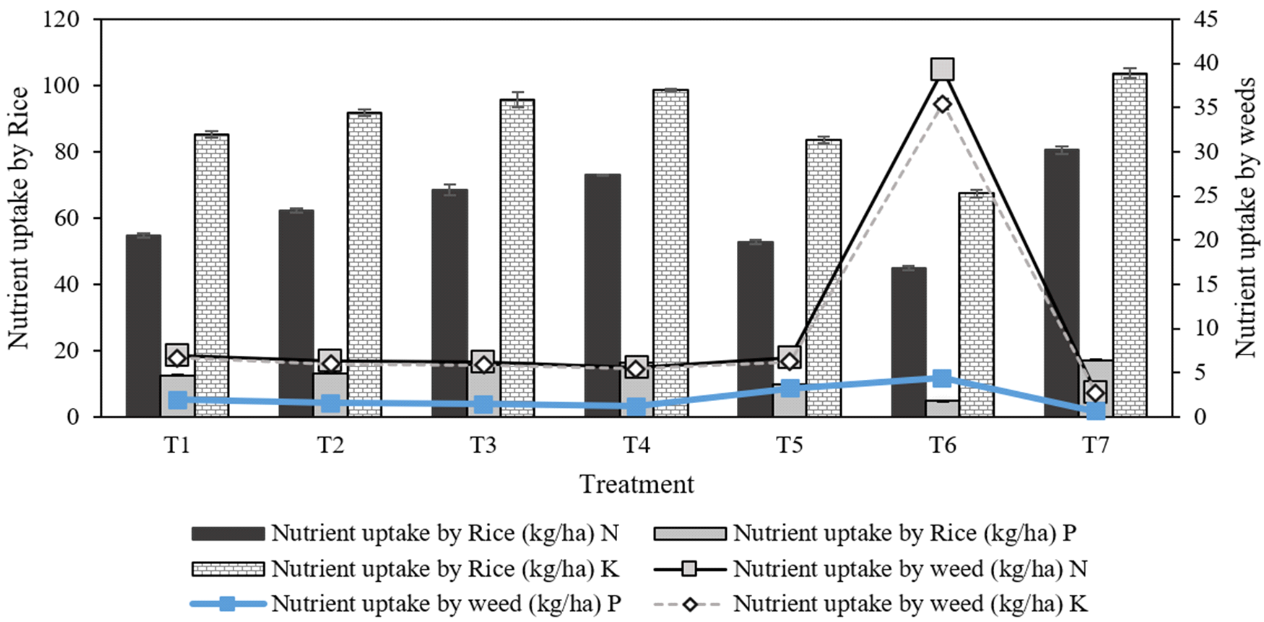

Figure 2. Nutrient uptake (kg/ha) by rice (column) and weeds (line) as affected by weed control treatments at rice harvesting

greater labor requirement and higher labor cost led to reduced benefit-cost ratio indicating that effective herbicide usage is highly efficient, non-laborious and economical than manual weeding.

Based on the findings of this study, it can be concluded that carfentrazone-ethyl 30 g/ha is an effective and safe alternative to the labour-intensive, time-consuming and costly hand weeding practice for controlling broad-leaved weeds and annual sedges predominating direct-seeded rice in the new alluvial zone of West Bengal.

REFERENCES

Banerjee H, Garai S, Sarkar S, Ghosh D, Samanta S and Mahato M. 2019. Efficacy of herbicides against canary grass and wild oat in wheat and their residual effects on succeeding greengram in coastal Bengal. *Indian Journal of Weed Science* **51**: 246.

Banerjee H, Samanta S, Sarkar S, Garai S, Pal S and Brahmachari K. 2018. Growth, productivity and nutrient uptake of different rice cultivars under coastal eco-system of West Bengal. *Journal of Indian Society of Coastal Agricultural Research* **36**(2): 115–121.

Biswas B, Timsina J, Patra SR, De D, Mishra B, Chakraborti R and Ray BR. 2019. Climate change-resilient rice production technology: A high yielding, water efficient and remunerative option for south Asian farmers. *Global Journal of Agricultural and Allied Sciences* **1**(1): 20–29.

Chakraborti M, Duary B and Datta M. 2017. Effect of weed management practices on nutrient uptake by direct seeded upland rice under Tripura condition. *International Journal of Current Microbiology and Applied Sciences* **6**(12): 66–72.

Chauhan BS, Singh RG and Mahajan G. 2012. Ecology and management of weeds under conservation agriculture: a review. *Crop Protection* **38**: 57–65.

Directorate of Agriculture. 2018. Estimates of area, yield rate and production of principal crops in West Bengal. Evaluation Wing, Directorate of Agriculture, Government of West Bengal: 23–36.

Gomez KA and Gomez AA. 1984. *Statistical procedures for agricultural research*. John wiley & sons.

Jackson ML. 1973. Soil chemical analysis, pentice hall of India Pvt. *Ltd., New Delhi, India*, **498**, 151–154.

Jaiswal DK and Duary B. 2023. Weed removal and crop nutrient uptake as affected by tillage and herbicides in direct-seeded rice-yellow mustard cropping sequence. *Indian Journal of Weed Science* **55**(3): 238–243.

Jana K, Mondal R and Mallick GK. 2020. Growth, productivity and nutrient uptake of aerobic rice (Oryza sativa L.) as influenced by different nutrient management practices. *Oryza-An International Journal on Rice* **57**(1): 49–56.

Jambhulkar N, Mondal B, Bisen J and Pradhan A. 2023. Growth and instability of rice production: a district level analysis in West Bengal, India. *Oryza-An International Journal on Rice* **60**: 487–494.

Kundu R, Mondal M, Garai S, Poddar R and Banerjee S. 2020. Efficacy of herbicides against broad-spectrum weed floras and their effect on non-target soil micro-organisms and productivity in sugarcane (*Saccharum* sp.). *Current Journal of Applied Science and Technology* **39**: 23–32.

Lampayan RM, Faronilo JE, Tuong TP, Espiritu AJ, De Dios JL, Bayot RS and Hosen Y. 2015. Effects of seedbed management and delayed transplanting of rice seedlings on crop performance, grain yield, and water productivity. *Field Crops Research* **183**: 303–314.

Patel SK, Chattopdhayaya N, Dubey DV and Namdeo B. 2023. Weed control by new generation herbicide and its influence on yield and nutrient uptake in transplanted rice. *International Journal of Plant & Soil Sci*ence **35**(21): 994–1002.

Poddar R, Ghosh RK, Paul T and Bera S. 2014. Weed management through oxyfluorfen in direct seeded rice and its impact on soil micro-organisms and succeeding crops. *Annals of Agricultural Research* **35**(3): 337–342.

Punia SS, Singh SK and Poonia TM. 2018. Bio-efficacy of carfentrazone-ethyl 40% DF against weeds in wheat and its carryover effect on succeeding sorghum. *Indian Journal of Weed Science* **45**(3): 159–162.

Raj SK, Jose N, Mathew R and Leenakumary S. 2013. Chemical management of non-grassy weeds in direct-seeded rice. *Indian Journal of Weed Science* **45**(3): 159–162.

Rao AN. 2022. Weed management role in meeting the global food and nutrition security challenge. *Indian Journal of Weed Science* **54**(4): 345–356.

Rao AN and Chandrasena N. 2024. Recent Developments in Rice Weed Management in India. *Weeds – Journal of the Asian-Pacific Weed Science Society* **6**(1): 1–20.

Rao AN, Singh RG, Mahajan G and Wani SP. 2020. Weed research issues, challenges, and opportunities in India. *Crop Protection* **134**: 104451.

Rao AN, Wani SP, Ramesha MS and Ladha JK. 2017. Rice production systems. In: (Eds. B.S. Chauhan et al.), *Rice production worldwide* (pp. 185–205). Springer International Publishing AG.

Rao AN, Johnson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct seeded rice. *Advances in agronomy* **93**: 153–255.

Shinde VV, Jagtap DN, More VG, Mane MJ and Dademal AA. 2018. Study of Bio-efficacy and Phytotoxicity of Carfentrazone-ethyl 40% DF in Direct Seeded Rice. *International Journal of Bio-resource and Stress Management* **9**(6): 695–701.

Singh A, Singh RK, Kumar P and Singh S. 2013. Growth, weed control and yield of direct-seeded rice as influenced by different herbicides. *Indian Journal of Weed Science* **45**(4): 235–238.

Singh VP, Singh SP, Tripathi N, Singh MK and Kumar A. 2009. Bio efficacy of penoxsulam on transplanted rice weeds. *Indian journal of weed Science* **41**(1&2): 28–32.

Witkowski DA and Halling BP. 1989. Inhibition of plant protoporphyrinogen oxidase by the herbicide acifluorfen-methyl. *Plant Physiology* **90**(4): 1239–1242.

Yaduraju NT, Rao AN, Bhullar MS, Gill JS and Malik RK. 2021. Direct-Seeded Rice (DSR) in India: New opportunities for Rice Production and Weed management in post-COVID-19 pandemic period. *Weeds-Journal of the Asian-Pacific Weed Science Society* **3**(2): 30–48.