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RESEARCH ARTICLE

Efficacy of sequential herbicide applications in managing diverse weed flora and improving the productivity of transplanted rice

Maksud Hasan Shah[1]*, Bikas Mandal[1], Dhiman Mukherjee[1], T.M. Tanjina Tarannum[2] and Santanu Kundu[3]

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ABSTRACT

A research experiment was conducted in 2020 and 2021 at the Kalyani D-Block Farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India to assess the performance of sequential herbicide applications in managing diverse weed flora and improving the productivity of transplanted rice. The experiment was laid out in a randomized block design with four replications. Nine treatments, with various combinations of pre-emergence and post-emergence herbicides with different modes of action, were evaluated. The pre-emergence application (PE) of pretilachlor 50% EC (pretilachlor) 0.70 kg/ha followed by (*fb*) cono-weeder operation was most effective in suppressing both grasses and broad-leaved weeds, recording highest weed control efficiency and rice grain yield. It was statistically comparable to the sequential application of pretilachlor 0.70 kg/ha PE *fb* post-emergence application (PoE) of bispyribac-Na 25 g/ha at 25 DAT. Both treatments have significantly enhanced rice plant growth attributes viz., plant height, biomass and improved nutrient uptake. Thus, pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha PoE offers an efficient, profitable and sustainable weed management solution for transplanted rice.

Keywords: Bispyribac-sodium, Nutrient uptake, Pretilachlor, Sequential herbicides, Transplanted rice, Weed control efficiency

INTRODUCTION

Rice (*Oryza sativa* L.) is a world's most important cereal crop feeding over half of the global population and contributing 31% to India's total food consumption (Dhillon *et al.* 2018, Jahan *et al.* 2020). In India, it is cultivated on about 44 million hectares, producing 124 million tonnes annually, which represents roughly 21.5% of global production (DES 2024). To meet the projected demand of 197.4 million tonnes by 2050 for 1.64 billion people, production must rise despite constraints on land, water, labour, and agrochemicals (Ahmad *et al.* 2021). The weed infestation often poses a serious threat to crop productivity (Rao 2022). Weeds vigorously compete with rice for nutrients, light, and space, causing significant yield losses and serving as alternate hosts for pests and diseases (Hussain *et al.* 2021). Puddle-transplanted rice offers several agronomic benefits, such as effective weed suppression through standing water, minimized percolation losses, and improved nutrient availability (Choudhary *et al.* 2021). Despite these benefits, rice fields are commonly infested with diverse weed species, including annual grasses, broad-leaved weeds, and sedges, making effective weed control a persistent challenge (Choudhary and Dixit 2018).

Manual weeding, although traditionally considered the most reliable method, has become less feasible in recent years due to rising labour costs and shortages (Kaur *et al.* 2016). Hence, herbicides have emerged as an efficient and practical solution for weed control, reducing the need for intensive manual labour. They are particularly useful for managing weed species which are morphologically similar with the crop, where manual removal is difficult (Rao *et al.* 2017). Pre-emergence application (PE) of herbicides controls mainly early emergent weeds, whereas later emerging weeds are controlled by post-emergence application (PoE) of herbicides. Relying solely on one herbicide or repeatedly using the same mode of action can lead to the evolution of herbicide resistance in weeds and hence, using several herbicides with different modes of action applied sequentially can provide broader weed control and help delay resistance evolution (Mahajan and Chauhan 2015). Such integrated approaches are effective in

[1] Department of Agronomy, B.C.K.V, Mohanpur, West Bengal, India

[2] Division of Agronomy, Bangladesh Agriculture University, Bangladesh, Division of Agronomy, [3]ICAR-Indian Agricultural Research Institute, Delhi, New Delhi, India

* Corresponding author email: maksudhasanshah@gmail.com

minimizing yield losses, as it enhance overall efficacy and ensure broader weed control (Shah *et al.* 2023). Thus, a field study was conducted at Bidhan Chandra Krishi Viswavidyalaya, to assess the performance of sequential herbicide applications in managing diverse weed flora to improve productivity of transplanted rice in the subtropical region.

MATERIALS AND METHODS

The field study was carried out during the *Kharif* seasons of 2020 and 2021 at the research farm of Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani, India. The experimental site lies at 18.1243° N latitude and 84.5447° E longitude, with an average elevation of 257 m above sea level. The area receives about 1150 mm of annual rainfall, with approximately 85% occurring during the south-west monsoon. The climate of the region is subtropical, marked by hot summers and relatively mild winters. The average minimum temperature in January is around 22.7°C, while May records the highest average temperature of about 43°C. The experimental field had clay loam soil, composed of 32.8% clay, 21.7% silt, and 45.5% sand. The soil pH ranged from 6.8 to 7.2, indicating a neutral reaction, and contained a moderate level of organic carbon (0.46%). The study was carried out using the rice variety '*IET 4786'* (Shatabdi), with a planting geometry of 20 cm × 10 cm. The experiment was arranged in a randomized complete block design (RCBD) consisting of nine treatment combinations with four replications **(Table 1**). The treatments were oxadiargyl 80% WP (oxadiargyl) 0.1 kg/ha PE followed by *(fb)* 2,4-D 0.5 kg/ha PoE 25 days after transplanting (DAT); pretilachlor 0.70 kg/ha PE; pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 10% SC (bispyribac-Na) 25 g/ha at 25 DAT; pretilachlor 0.70 kg/ha PE *fb* cyhalofop-butyl 5.1% + penoxsulam 1.02% OD (RM) (cyhalofop-butyl + penoxsulam) 112.5 + 22.5 g/ha PoE at 25 DAT; oxadiargyl 0.1 kg/ha *fb* passing of cono-weeder at 25 DAT; pretilachlor 0.70 kg/ha PE *fb* passing of conoweeder at 25 DAT; pretilachlor 0.70 kg/ha PE *fb* triafamone + ethoxysulfuron 44.0+22.5 g/ha PoE at 25 DAT; hand weeding twice at 20 and 40 DAT and weedy check. Each plot was 5 m × 4 m in size. Herbicide treatments were applied using a knapsack sprayer fitted with a flat-fan nozzle, delivering 500 L/ha of spray solution. Fertilizers were supplied at 80:40:40 kg N, P, and K per hectare using urea (N) and muriate of potash (K). Phosphorus and potassium were applied at transplanting, while nitrogen was split into three doses before transplanting, and at 30 and 60 DAT. The observations on weeds were recorded at 30 and 45 DAT. Weed density and biomass were measured with a 50 cm × 50 cm quadrat placed randomly at three spots per plot. Samples were sun-dried, then oven-dried at 65°C until constant weight, and expressed as weed biomass (g/m²). Weed control efficiency (WCE) was estimated from weed biomass measurements to evaluate the performance of various herbicide treatments. The formula used for WCE is as follows:

$$\text{WCE (\%)} = (\frac{\text{WDc} - \text{WDt}}{\text{WDC}}) \text{ x } 100$$

Where, WD_c = Weed dry matter accumulation recorded in the untreated control plot and WD_t = Weed dry matter production was measured in the plots receiving herbicide treatments.

To homogenize the variance, weed density and biomass data were transformed using the square root formula $\sqrt{x+0.5}$. Grain yield, recorded in kg per plot, was converted to kg/ha and then expressed in t/ha. The data were statistically analysed through analysis of variance (ANOVA) appropriate for the experimental design, and treatment differences were tested using the F-test at a 5% significance level (Gomez and Gomez 1984). Since the year-to-year variation was minimal and not statistically significant in most of the parameters, the data from both years were combined and presented as pooled results.

A linear regression line is commonly used to the model relationship between variables of interest, where 'y' denotes the dependent variable and 'x' represents the independent variable (Garai *et al.*, 2023). The equation includes two key parameters: 'b' (the regression coefficient or slope) and 'c' (the intercept), both of which are estimated through regression analysis. The goodness of fit of the model is often assessed using the coefficient of determination (R^2), This represents the share of total variation in the dependent variable that can be accounted for by the independent variable. The R^2 value ranges between 0 and 1, where values closer to 1 indicate a stronger model fit to the data.

RESULTS AND DISCUSSION

Effect on weeds

The dominant grasses observed during the experiment were: *Cynodon dactylon, Echinochloa colona, Panicum repens*; and the broad-leaved weeds were: *Ludwigia parviflora*, *Alternanthera philoxeroides, Malva neglecta* and *Eclipta alba*. The major sedges were *Cyperus iria* and *Fimbristylis miliacea*. During the experimental period, broad-leaved weeds were the most dominant, followed by grasses and sedges (**Table 1**). At 30 and 45 days after transplanting (DAT), pretilachlor 0.70 kg/ha PE *fb* passing of conoweeder recorded the minimum density of *Cynodon dactylon* and *Echinochloa colona* and was statistically superior over other treatments (**Table 1**). The distribution of E. *colona* in the order of decreasing density in response to herbicides application was: pretilachlor PE *fb* bispyribac-Na PoE > pretilachlor PE *fb* triafamone + ethoxysulfuron PoE > pretilachlor PE *fb* cyhalofop-butyl + penoxsulam PE > hand weeding twice at 20 and 40 DAT, with percentage share of 16.23%, 23.07%, 44.05%, and 54.67% of total weed density, respectively. *Ludwigia parviflora* was observed only with pretilachlor 0.70 kg/ha as PE *fb* passing of conoweeder and weedy check. *Eclipta alba* was the most abundant weed species, showing the highest density in untreated control plots, followed by plots treated with pretilachlor 0.70 kg/ha, hand weeding twice at 20 and 40 DAT, oxadiargyl 0.1 kg/ha as PE *fb* 2,4-D 0.5 kg/ha POE and oxadiargyl 0.1 kg/ha as PE *fb* passing of conoweeder. The pretilachlor 0.70 kg/ha PE *fb* passing of conoweeder and pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha POE recorded the lowest density of *Eclipta alba.* Rishi *et al.* (2016) reported that the sequential application of pendimethalin PE *fb* bispyribac-Na PoE significantly lowered the density of *Eclipta alba* and *Panicum repens* compared to sole applications of pendimethalin PE, butachlor PE, oxadiargyl PE, ethoxysulfuron PoE, bispyribac-sodium PoE, and the untreated control at 30 and 45 DAT in rice.

The density of *Cyprus iria* was highest in weedy check, followed by pretilachlor 0.70 kg/ha PE, oxadiargyl 0.1 kg/ha as PE *fb* passing of conoweeder, oxadiargyl 0.1 kg/ha PE *fb* 2,4-D 0.5 kg/ha PoE and hand weeding twice at 20 and 40 DAT. Pretilachlor 0.70 kg/ha PE *fb* passing of conoweeder resulted in best control of *Panicum repens*. *Malva neglecta* density was least with pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha POE, while highest with pretilachlor 0.70 kg/ha PE. *Fimbristylis miliacea* was observed only with pretilachlor 0.70 kg/ha PE *fb* passing of conoweeder and its highest density was found in weedy check. The efficacy of pretilachlor in effectively managing grasses like *Echinochloa* spp. was previously observed widely across South Asia (Singh *et al.* 2015, Chatterjee *et al.* 2021, Shah *et al.*

Table 1. Effect of weed management treatments on the weed density in transplanted rice at 30 DAT (2 years pooled data)

Treatment	Weed density (no./ m²)									
	Grasses			Broad-leaved weeds					Sedges	
	Cynodon dactylon	*Echinochloa colona*	*Panicum repens*	*Ludwigia parviflora*	*Alternanthera philoxeroides*	*Malva neglecta*	*Eclipta alba*	Other BLW	*Cyperus iria*	*Fimbristylis miliacea*
Oxadiargyl 0.1 kg/ha PE *fb* 2,4-D 0.5 kg/ha PoE	1.62 (2.14)	2.12 (3.98)	1.92 (3.20)	1.27 (1.11)	1.32 (1.26)	1.60 (2.07)	1.76 (2.61)	1.66 (2.25)	1.62 (2.12)	1.50 (1.75)
Pretilachlor 0.70 kg/ha PE	1.70 (2.39)	2.26 (4.63)	2.17 (4.23)	1.31 (1.23)	1.39 (1.43)	1.65 (2.23)	1.82 (2.80)	1.79 (2.71)	1.75 (2.57)	1.55 (1.89)
Pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha POE	1.18 (0.89)	1.55 (1.91)	1.48 (1.68)	1.04 (0.58)	1.03 (0.57)	1.10 (0.71)	1.54 (1.86)	1.47 (1.66)	1.46 (1.63)	1.21 (0.96)
Pretilachlor 0.70 kg/ha PE *fb* cyhalofop-butyl 112.5 + penoxsulam 22.5 g/ha (RM) as PoE	1.48 (1.71)	1.83 (2.86)	1.74 (2.52)	1.23 (1.03)	1.14 (0.81)	1.27 (1.12)	1.67 (2.28)	1.66 (2.25)	1.57 (1.96)	1.37 (1.37)
Oxadiargyl 0.1 kg/ha as PE *fb* passing of conoweeder	1.63 (2.16)	2.20 (4.33)	2.06 (3.75)	1.34 (1.30)	1.30 (1.20)	1.60 (2.07)	1.76 (2.60)	1.77 (2.63)	1.68 (2.33)	1.51 (1.77)
Pretilachlor 0.70 kg/ha as PE *fb* passing of conoweeder	1.10 (0.72)	1.45 (1.60)	1.37 (1.37)	0.97 (0.45)	0.94 (0.38)	1.13 (0.78)	1.35 (1.33)	1.28 (1.14)	1.34 (1.29)	1.13 (0.78)
Pretilachlor 0.70 kg/ha PE *fb* triafamone+ ethoxysulfuron (44.0+22.5 g/ha) PoE	1.24 (1.03)	1.61 (2.08)	1.60 (2.06)	1.11 (0.74)	1.15 (0.82)	1.27 (1.12)	1.49 (1.73)	1.54 (1.88)	1.50 (1.76)	1.30 (1.19)
Hand weeding twice at 20 and 40 DAT	1.53 (1.83)	2.01 (3.53)	1.74 (2.54)	1.43 (1.55)	1.40 (1.46)	1.49 (1.72)	1.82 (2.80)	1.83 (2.84)	1.60 (2.06)	1.45 (1.62)
Weedy check (control)	2.52 (5.86)	3.62 (12.58)	3.39 (10.97)	1.99 (3.46)	2.48 (5.68)	2.59 (6.19)	2.80 (7.33)	2.98 (8.36)	2.38 (5.15)	1.92 (3.18)
LSD (p=0.05)	0.14	0.56	0.58	0.11	0.15	0.31	0.42	0.27	0.26	0.19

PE: pre-emergence application; PoE: post-emergence application; *fb:* followed by; DAT: days after transplanting

2025). Most of the pre-emergence herbicides are less effective against sedges, particularly those that spread through rhizomes and stolons rather than cell division, which limits their control efficiency (Rao *et al.* 2007, Singh and Singh 2012, Singh *et al.* 2015, Chatterjee *et al.* 2021, Shah *et al.* 2025). Their relatively low persistence capability under hot and humid conditions further reduces their ability to suppress weeds at later growth stages (Saha *et al.* 2021). In contrast, post-emergence application of bispyribac-Na, either alone or in combination with pyrazosulfuron, has shown strong efficacy against grassy weeds, broad-leaved weeds and sedges, particularly *Cyperus iria*, the predominant sedge species in the area (Jat and Singh 2021, Saha *et al.* 2021). Similarly, Mitra *et al.* (2022) also reported the highest reduction in weed biomass at both 35 and 55 DAT with sequential use of pendimethalin as PE followed by bispyribac + pyrazosulfuron as PoE.

Pretilachlor 0.70 kg/ha PE *fb* conoweeder recorded the lowest weed density and biomass, with highest weed control efficiency followed by pretilachlor *fb* bispyribac-Na and pretilachlor *fb* triafamone + ethoxysulfuron (**Table 2** and **3**) confirming Meena *et al.* (2019), Menon (2019) and Arthanari (2023). Pretilachlor and oxadiargyl alone were less effective than the other herbicides, but all herbicide applications showed superior performance compared to the weedy check in both years. Lower weed densities were due to effective sequential application, where PE herbicides suppressed early weeds and PoE herbicides, particularly bispyribac-Na, managed later emerged weeds. Pretilachlor alone was less effective (62.05% reduction), indicating that single herbicide applications are inadequate for broad-spectrum weed control. Sequential use of pretilachlor *fb* bispyribac-Na effectively managed mixed weed flora in transplanted rice with pretilachlor controlling grasses and some broad-leaved weeds and bispyribac-Na suppressing sedges, broad-leaved, and late emerging weeds. Combining PE and PoE herbicides, whether in sequence or compatible mixes with different modes of action, provided superior weed suppression.

Pretilachlor *fb* bispyribac-sodium showed high efficacy due to their complementary mode of actions. Pretilachlor, a chloroacetamide herbicide, inhibits very long chain fatty acid biosynthesis in target weeds by blocking the Acetyl-CoA carboxylase (ACCase) enzyme, disrupting cell membrane formation and other lipid structures essential for growth, leading to plant death (Shilpakar *et al.* 2020). It primarily targets grassy weeds in rice and is absorbed through roots or foliage, translocating

Table 2. Effect of weed management treatments on the weed density in transplanted rice at 45 DAT (2 years pooled data)

Treatment	Weed density (no./ m^2)									
	Grasses			Broad-leaved weeds					Sedges	
	Cynodon dactylon	*Echinochloa colona*	*Panicum repens*	*Ludwigia parviflora*	*Alternanthera philoxeroides*	*Malva neglecta*	*Eclipta alba*	Other BLW	*Cyrus iria*	*Fimbristylis miliacea*
Oxadiargyl 0.1 kg/ha PE *fb* 2,4-D 0.5 kg/ha PoE	1.82 (2.81)	2.99 (8.43)	2.21 (4.38)	1.67 (2.29)	1.57 (1.96)	1.99 (3.47)	2.17 (4.19)	1.99 (3.45)	1.73 (2.48)	1.54 (1.86)
Pretilachlor 0.70 kg/ha PE	1.93 (3.23)	3.24 (9.97)	2.54 (5.94)	1.70 (2.39)	1.61 (2.11)	1.97 (3.39)	2.17 (4.22)	2.09 (3.85)	1.86 (2.97)	1.60 (2.06)
Pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha POE	1.49 (1.72)	2.44 (5.45)	1.82 (2.82)	1.32 (1.24)	1.13 (0.79)	1.47 (1.68)	1.94 (3.26)	1.81 (2.77)	1.51 (1.79)	1.26 (1.10)
Pretilachlor 0.70 kg/ha PE *fb* cyhalofop-butyl 112.5 + penoxsulam 22.5 g/ha (RM) as PoE	1.77 (2.62)	2.70 (6.81)	1.90 (3.12)	1.50 (1.76)	1.32 (1.26)	1.77 (2.65)	2.07 (3.80)	1.97 (3.38)	1.67 (2.30)	1.43 (1.55)
Oxadiargyl 0.1 kg/ha as PE *fb* passing of conoweeder	1.92 (3.17)	3.04 (8.74)	2.34 (4.98)	1.70 (2.39)	1.64 (2.18)	1.91 (3.15)	2.14 (4.08)	2.08 (3.81)	1.78 (2.66)	1.56 (1.94)
Pretilachlor 0.70 kg/ha as PE *fb* passing of conoweeder	1.36 (1.35)	2.24 (4.51)	1.65 (2.22)	1.34 (1.29)	1.05 (0.59)	1.27 (1.12)	1.75 (2.57)	1.52 (1.81)	1.43 (1.54)	1.20 (0.94)
Pretilachlor 0.70 kg/ha PE *fb* triafamone+ ethoxysulfuron (44.0+22.5 g/ha) PoE	1.55 (1.91)	2.55 (6.03)	1.83 (2.84)	1.49 (1.71)	1.25 (1.06)	1.69 (2.37)	1.90 (3.12)	1.87 (3.01)	1.57 (1.96)	1.33 (1.27)
Hand weeding twice at 20 and 40 DAT	1.79 (2.70)	2.87 (7.72)	1.98 (3.43)	1.70 (2.39)	1.57 (1.97)	1.89 (3.09)	2.17 (4.22)	2.03 (3.63)	1.69 (2.37)	1.50 (1.74)
Weedy check (control)	2.87 (7.77)	5.17 (26.26)	4.03 (15.72)	2.89 (7.85)	2.74 (7.00)	2.92 (8.01)	3.43 (11.26)	3.67 (12.95)	2.54 (5.96)	2.08 (3.82)
LSD (p=0.05)	0.22	0.93	0.64	0.27	0.18	0.31	0.46	0.34	0.27	0.19

PE: pre-emergence application; PoE: post-emergence application; *fb:* followed by; DAT: days after transplanting

throughout the plant. On the other hand, bispyribac-Na inhibits branched-chain amino acid biosynthesis in target weeds by blocking the Aceto- Lactate-Synthetase (ALS) enzyme, effectively controlling a broad spectrum of weeds with a favourable eco-toxicological profile. Chaudhury and Dixit (2024) reported earlier the greater efficacy of bispyribac-Na against *Echinochloa crusgalli* when applied at 25 DAT. Similarly, pretilachlor *fb* triafamone + ethoxysulfuron was effective against grasses and sedges as observed earlier by Yadav *et al.* (2019). Additionally, sequential application of pretilachlor *fb* 2,4-D also effective in controlling broad-leaved weeds. Penoxsulam was also effective in suppressing both grasses and sedges up to 60 DAT (Jehangir *et al.* 2022).

Effect on transplanted rice

The pretilachlor 0.70 kg/ha PE *fb* passing of conoweeder improved rice growth, yield attributes (**Figure 2**) and nutrient uptake (**Table 4**). This combination achieved the maximum grain yield, which was approximately 2.18 times greater than the yield under the weedy check. Other combinations, such as pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha PoE and pretilachlor 0.70 kg/ha PE *fb* triafamone+ ethoxysulfuron (44.0+22.5 g/ha) PoE were also found to be effective in improving rice growth, yield attributes and nutrient uptake confirming the findings of Mukherjee (2020) and Shah *et al.* (2023). These results highlight the role of herbicides as an important component of integrated weed management for reducing weed competition and create suitable conditions for crop development, which in turns enhance rice productivity.

Improved yield attributes under these treatments, due to lower weed pressure, facilitated greater dry matter accumulation and nutrient absorption, thereby enhancing photosynthate availability for grain formation (Mukherjee 2020). This combined PE and POE approach collectively contributed to the improved crop growth conditions and nutrient uptake, ultimately leading to enhanced grain yield by 61.20% to 123.64%. Similar observations were made by Kaur and Singh (2015), Saha *et al.* (2021) and Mitra *et al.* (2022). The minimum yield was recorded in the weedy check treatment, primarily due to severe competition for nutrients, light, and moisture (Choudhary *et al.* 2021, 2024).

Rice yield losses from weed interference varied between 1% and 58.39% (**Figure 2**), with the highest reduction of 58.39% observed in the weedy check. Pretilachlor 0.70 kg/ha PE *fb* passing of conoweeder recorded lower yield loss of 1% followed by pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha PoE with 4.29% yield loss due to uncontrolled weeds.

Rice grain yield was found to be significant negative linear correlation with weed density and biomass (**Figure 1**). Regression analysis showed that for weed biomass, $y = -0.0669x + 5.92$ ($R^2 = 0.81$), each unit increase reduced yield by 0.066 t/ha, explaining 81% of yield variation. For weed density, $y = -0.0542x + 6.36$ ($R^2 = 0.89$), each unit increase lowered yield by 0.054 t/ha, accounting for 89% of

Table 3. Effect of weed management treatments on the total weed density, biomass, WCE and nutrient removal by weeds in transplanted rice (pooled data of two years)

Treatment	Total Weed density (no./m^2) (30 DAT)	Total Weed density (no./ m^2) (45 DAT)	Total Weed biomass (g/ m^2) (30 DAT)	Total Weed biomass (g/ m^2) (45 DAT)	WCE (%) (30 DAT)	WCE (%) (45 DAT)	Removal of nutrients by weeds (kg/ha)			Removal of total nutrient by weeds (kg/ha)
							N	P	K	
Oxadiargyl 0.1 kg/ha PE *fb* 2,4-D 0.5 kg/ha PoE	22.46	35.31	10.62	12.28	79.34	76.01	2.39	0.38	2.32	5.09
Pretilachlor 0.70 kg/ha as PE	26.08	40.13	12.29	14.78	72.64	71.13	2.76	0.39	2.69	5.84
Pretilachlor 0.70 kg/ha as PE *fb* bispyribac-Na 25 g/ha as POE	12.44	22.60	5.18	6.41	89.29	87.48	1.16	0.18	1.14	2.48
Pretilachlor 0.70 kg/ha as PE *fb* cyhalofop-butyl 112.5 + penoxsulam 22.5 g/ha (RM) as PoE	17.90	29.23	8.08	9.82	82.59	80.82	1.82	0.28	1.77	3.87
Oxadiargyl 0.1 kg/ha as PE *fb* passing of conoweeder	24.13	37.09	11.70	13.21	74.52	74.19	2.63	0.41	2.56	5.60
Pretilachlor 0.70 kg/ha as PE *fb* passing of conoweeder	9.83	17.94	4.11	5.58	90.78	89.10	0.93	0.14	0.90	1.97
Pretilachlor 0.70 kg/ha as PE *fb* triafamone + ethoxysulfuron 44.0 + 22.5 g/ha PoE	14.40	25.27	6.52	8.17	86.02	84.04	1.49	0.23	1.43	3.15
Hand weeding twice at 20 and 40 DAT	21.88	3.24	9.82	1.97	80.37	96.15	2.21	0.34	2.15	4.70
Weedy check (control)	68.73	106.59	48.71	51.19	0.00	0.00	10.84	1.72	10.56	23.12
LSD (p=0.05)	2.93	3.80	1.81	1.95	7.56	6.80	0.30	0.05	0.30	0.65

PE: pre-emergence application; PoE: post-emergence application; *fb:* followed by; DAT: days after transplanting

Table 4. Effect of weed management treatments on growth parameters, nutrient uptake and yield of transplanted rice (pooled data of two years)

Treatment	Plant height (30 DAT)	Plant height (45 DAT)	Plant dry matter (30DAT)	Plant dry matter (45 DAT)	Nutrient uptake by rice			Total uptake by rice (kg/ha)
					N	P	K	
Oxadiargyl 0.1 kg/ha PE *fb* 2,4-D 0.5 kg/ha PoE	70.49	85.53	90.93	356.22	115.64	16.13	187.29	319.06
Pretilachlor 0.70 kg/ha PE	75.28	86.97	80.72	338.31	108.19	15.09	175.26	298.54
Pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha PoE	78.81	93.65	107.43	391.74	138.37	19.18	217.33	374.88
Pretilachlor 0.70 kg/ha PE *fb* cyhalofop-butyl 112.5 + penoxsulam 22.5 g/ha (RM) as PoE	73.08	88.14	97.50	402.09	125.23	17.45	201.84	344.52
Oxadiargyl 0.1 kg/ha as PE *fb* passing of conoweeder	69.00	84.03	89.56	354.06	110.67	15.42	178.44	304.53
Pretilachlor 0.70 kg/ha as PE *fb* passing of conoweeder	81.82	96.97	113.61	398.77	144.72	20.06	227.34	392.12
Pretilachlor 0.70 kg/ha PE *fb* triafamone+ ethoxysulfuron (44.0+22.5 g/ha) PoE	75.27	90.13	101.14	384.24	131.60	18.30	209.72	359.62
Hand weeding twice at 20 and 40 DAT	71.53	86.86	92.76	389.82	121.49	16.96	197.66	336.11
Weedy check (control)	60.55	73.73	71.75	298.55	74.17	10.52	130.28	214.97
LSD (p=0.05)	8.08	7.28	8.44	28.17	13.03	1.80	21.16	35.99

PE: pre-emergence application; PoE: post-emergence application; *fb:* followed by; DAT: days after transplanting

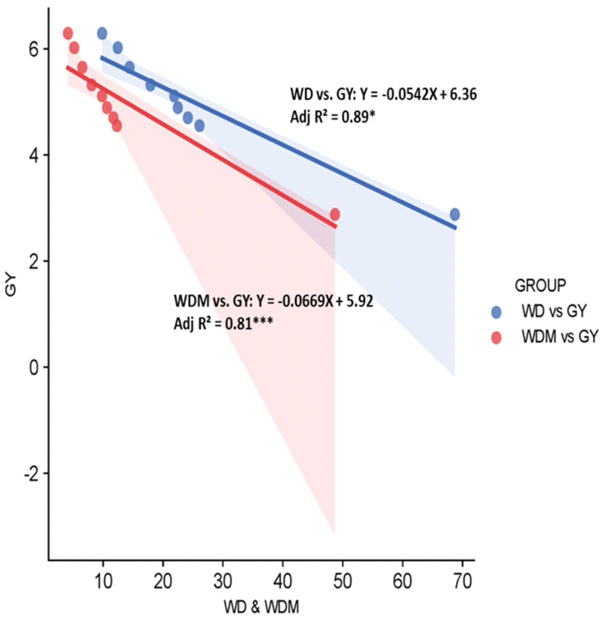

Figure 1. Linear regression model between weed density (WD), weed biomass (WDM), and grain yield (GY) by considering GY as dependent variable.

*Significant at p<0.05, **Significant at p<0.01, *** Significant at p<0.001.

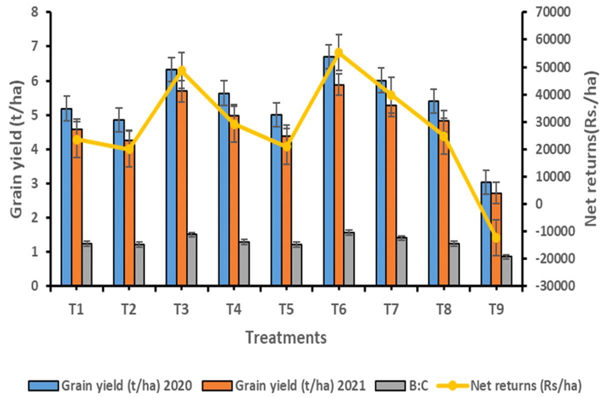

Figure 2. Significance chart for weed management treatments on transplanted rice grain yield, net returns and benefit cost ratio

*Oxadiargyl 0.1 kg/ha as PE *fb* 2,4-D 0.5 kg/ha at 25 DAT POE (T_1); pretilachlor 0.70 kg/ha PE (T_2); pretilachlor 0.70 kg/ha as PE *fb* bispyribac-Na 25 g/ha PoE 25 DAT (T_3); pretilachlor 0.70 kg/ha PE *fb* cyhalofop-butyl + penoxsulam 112.5 + 22.5 g/ha (RM) POE 25 DAT (T_4); oxadiargyl 0.1 kg/ha PE *fb* passing of conoweeder at 25 DAT (T_5); pretilachlor 0.70 kg/ha PE *fb* passing of cono-weeder at 25 DAT (T_6); pretilachlor 0.70 kg/ha PE *fb* triafamone + ethoxysulfuron 44.0+22.5 g/ha POE 25 DAT (T_7), hand weeding twice at 20 and 40 DAT (T_8) and weedy check (T_9)

variation. These findings emphasize the crucial role of effective weed management in achieving maximum rice yield.

Significantly highest net returns (₹ 55,289/ha) and B:C ratio (1.57) were achieved with pretilachlor 0.70 kg/ha PE followed by conoweeder, which was statistically similar to pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha (₹ 48647 and 1.51), based on pooled data (**Figure 2**). Similar results were reported by Mohapatra *et al.* (2021).

Conclusion

It was concluded that pretilachlor 0.70 kg/ha PE *fb* bispyribac-Na 25 g/ha PoE was most efficient in achieving maximum rice yield due to an effective, economic and broad-spectrum weed management in transplanted rice in West Bengal. Pretilachlor 0.70 kg/ha PE *fb* passing of conoweeder was found to be equally effective in lowering weed density, biomass and increasing transplanted rice grain yield.

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