



Bio-efficacy and phytotoxicity of pre-emergence herbicide mixtures on weed growth and yield in transplanted rice (*Oryza sativa*)

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Rice (*Oryza sativa* L.) is the most important cereal crop and also a staple food for over half of the world's population and provides up to 50% of the calories needed by millions of Asians who live in poverty (Muthayya *et al.* 2013). Southeast Asian's daily caloric needs are met up to 76% with its consumption (Fitzgerald *et al.* 2009). Weeds are a major contributor in reduction in rice yield (Jabran *et al.* 2018) beside other biotic, abiotic factors and inadequate crop management. Sedges, grasses and broad-leaved weeds in transplanted conditions can reduce rice crop output by as much as 76% (Singh *et al.* 2004). The rice plant experiences severe competition with these weeds if not controlled before the critical period of crop growth. The conventional method of controlling weeds by hand weeding is becoming less popular due to labour shortage during crucial weeding times and the cost involved with this process (Kumar and Ladha 2011). Compared to other weed management methods, application of selective herbicides is more practical way of weed control to farmers as they are simple to apply, effective as well as more time and money-efficient (Singh *et al.* 2016). Utilisation of herbicides having different chemical compositions in the field can avoid residue accumulation, prevent shift in weed flora and development of herbicide resistance in weeds. Pre-emergence herbicide mixtures are combinations of herbicides specifically designed to control and target weeds at their earliest stages of growth, thereby reducing competition for resources. Keeping this in view, a field experiment was conducted to evaluate the bio-efficacy and phytotoxicity of pre-emergence herbicide mixtures on weed growth and yield in transplanted rice.

The experiment was conducted during rainy (*kharif*) season of 2023 at the Agricultural Research Farm, Institute

of Agricultural Sciences, Banaras Hindu University, Varanasi (25°15'25"N, 82°59'29"E; at an elevation of 75.5 m amsl), Uttar Pradesh using transplanted rice cv. 'Samba mahsuri' (BPT-5204). The experiment was laid out in randomised block design having nine treatments replicated thrice including one untreated control. Soil type of experimental field was sandy clay loam in texture having pH 7.84. The treatment comprised of T₁, Metsulfuron methyl + chlorimuron ethyl + pretilachlor @452.4 g a.i./ha; T₂, Metsulfuron methyl + chlorimuron ethyl + pretilachlor @603.2 g a.i./ha; T₃, Metsulfuron methyl + chlorimuron ethyl + pretilachlor @754 g a.i./ha; T₄, Pretilachlor + pyrazosulfuron ethyl @615 g a.i./ha; T₅, Bensulfuron methyl + pretilachlor @660 g a.i./ha; T₆, Weedy check; T₇, Metsulfuron methyl + chlorimuron ethyl + pretilachlor @942.5 g a.i./ha; T₈, Metsulfuron methyl + chlorimuron ethyl + pretilachlor @1,508 g a.i./ha; T₉, Oxidiazon + pretilachlor @520 + 150 mL a.i./ha. These pre-emergence herbicides mixtures were applied in form of ready mix. Paddy seedlings were manually transplanted on 14th July, 2023 in puddled soil by maintaining the inter-row spacing of 20 cm and plant to plant spacing of 10 cm. Herbicides were applied 3 days after transplanting (DAT) in the experimental plot as per the treatment. The fertiliser dose of 120 kg N, 60 kg P₂O₅ and 60 kg K₂O/ha was followed. Phosphorus and potassium were applied in the field as basal dose at the time of transplanting in the form of DAP and MOP, respectively to all the plots. Nitrogenous fertiliser was applied through urea and DAP in three split doses (50% as basal dose + 25% as top dressing at tillering stage + 25% at panicle initiation stage). Respective herbicide mixtures as per the treatments were mixed with 50 kg of sand/ha on the day of application and applied uniformly to the field in 2.5 cm depth of water. Water was not drained for two days and fresh irrigation was not given in the field. Observations were recorded on weed density, weed biomass, plant growth attributes, yield attributes and yield. Crop phytotoxicity level was measured on a scale of 0–10: 0–1, None; 1–3, Slight; 4–6, Moderate;

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7–9, Severe; 10, Complete phytotoxicity.

Weed flora consisting of *Cynodon dactylon*, *Echinochloa colona*, *Paspalum distichum* and *Cyperus rotundus*, *Fimbristylis miliacea*, *Cyperus difformis* among grasses and sedges, respectively; *Ipomoea aquatica*, *Sagittaria guayanensis*, *Marsilea quadrifolia*, *Eclipta prostrata* and *Rotala densiflora* were found among broad-leaved weeds at the experimental field. The floral composition of weeds in the field at 30 days after herbicide application (DAA), consisted of 86% grasses and 14% sedges. At 60 DAA, weed composition of grasses, sedges and broad-leaved weeds was 58%, 23% and 19%, respectively (Table 1). The different weed species increased with crop up to 60 days and then gradually declined. This pattern can be explained by the fact that grasses germinate at early stage of crop growth whereas sedges and broad-leaved weeds germinate during later stages of crop growth.

Weed density and biomass: Treatment T₉ recorded significantly the lowest weed density of grasses, sedges, broad-leaved weeds and the total number of weeds at 30 DAA. Regarding grassy weeds of the field same trend was noticed during 60 DAA. However, regarding broad-leaved weeds and sedges at 60 DAA, this treatment was statistically similar with T₈ and T₄ (Table 1).

Dry weight of grasses and sedges was also significantly the lowest in plots applied with treatment T₉ and this was

at par with all other treatments except weedy check at 30 DAA and 60 DAA. From statistical analysis it was found that treatments T₁ and T₃ were not as significantly efficient as the other treatments in study regarding the dry weight of broad-leaved weeds (Table 2). Pretilachlor belongs to chloroacetamide group of herbicides which inhibits growth and reduce cell division after the application, it quickly spreads on soil and disrupts cell division of germinating seeds of different types of weeds whereas oxidiazon forms a barrier or film on the soil surface, where it inhibits the synthesis of chlorophyll in germinating weed seeds. Shahabuddin *et al.* (2016) reported that pretilachlor and oxadiazon as a pre-emergence herbicide performed the best in terms of controlling different types of grasses, broad-leaved weeds and sedges in rice and resulting in lower weed biomass.

Growth attributes: For the growth attributes treatment T₈ recorded significantly tallest plant height, maximum LAI and dry matter accumulation at 60 DAT (Table 3). Similar results were reported by Mohapatra *et al.* (2017). At 60 DAT, T₉ recorded significantly highest tillers number/m² and SPAD reading. This might be due to better weed control and consequently more growth resources availability under reduced weed competition.

Yield attributes: Among all the treatments, T₉ recorded significantly the highest value of yield attributes, viz. number

Table 1 Effect of pre-emergence herbicide mixtures on weed density

Treatments	Weed density (Nos/m ²)						
	30 DAA			60 DAA			
	Grasses	Sedges	Total	Grasses	Sedges	BLWs	Total
T ₁	14.21 ^{ab} (201)	2.38 ^b (5)	16.59 ^{ab} (275)	12.17 ^{ab} (147)	5.43 ^b (29)	8.98 ^{bc} (80)	26.58 ^b (705)
T ₂	12.8 ^{ab} (163)	3.31 ^{ab} (10)	16.11 ^{ab} (259)	9.96 ^b (99)	5.88 ^b (34)	6.37 ^{de} (40)	22.21 ^{cde} (492)
T ₃	13.47 ^{ab} (181)	3.91 ^{ab} (14)	17.38 ^{ab} (301)	11.2 ^b (124)	5.67 ^b (31)	9.19 ^b (83)	26.06 ^{bc} (678)
T ₄	13.83 ^{ab} (191)	2.46 ^b (5)	16.29 ^{ab} (264)	10.24 ^b (103)	4.69 ^{bc} (21)	6.90 ^{cde} (47)	21.83 ^{de} (476)
T ₅	12.85 ^{ab} (164)	3.16 ^{ab} (9)	16.01 ^b (256)	9.64 ^b (91)	4.79 ^{bc} (22)	7.84 ^{bcd} (60)	22.26 ^{cde} (495)
T ₆	16.72 ^a (279)	5.73 ^a (32)	22.45 ^a (502)	14.73 ^a (215)	9.93 ^a (98)	14.23 ^a (201)	38.90 ^a (1512)
T ₇	12.88 ^{ab} (165)	2.89 ^{ab} (8)	15.77 ^b (247)	10.15 ^b (102)	5.15 ^b (26)	8.72 ^{bc} (75)	24.02 ^{bcd} (576)
T ₈	10.77 ^b (115)	1.95 ^b (3)	12.72 ^b (161)	9.98 ^b (99)	4.52 ^{bc} (20)	5.22 ^c (26)	19.74 ^c (389)
T ₉	10.06 ^b (100)	1.59 ^b (2)	11.66 ^b (135)	9.76 ^b (94)	3.21 ^c (9)	5.90 ^{de} (34)	18.87 ^e (355)
SEM±	1.58	0.81	1.79	0.79	0.53	0.58	1.09
CD (p=0.05)	5.62	2.90	6.35	2.83	1.90	2.09	3.88

Data were subjected to square root $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values. Means followed by same letters are not significantly different. DAA, Days after herbicide application; BLWs, Broad-leaved weeds. Refer to Methodology for treatment details.

Table 2 Effect of pre-emergence herbicide mixtures on weed dry weight at 30 and 60 days after herbicide application

Treatments	Weed dry weight (g/m ²)						
	30 DAA			60 DAA			
	Grasses	Sedges	Total	Grasses	Sedges	BLWs	Total
T ₁	8.02 ^{ab} (63.9)	1.53 ^b (1.84)	9.55 ^b (90.70)	7.46 ^b (55.15)	4.03 ^b (15.74)	8.72 ^b (75.53)	20.20 ^{bc} (407.54)
T ₂	7.79 ^b (60.18)	1.30 ^b (1.19)	9.09 ^b (82.12)	6.85 ^b (46.42)	4.09 ^b (16.12)	6.00 ^c (35.5)	16.94 ^{bcd} (286.46)
T ₃	6.73 ^b (44.79)	2.14 ^{ab} (4.07)	8.87 ^b (78.17)	7.08 ^b (49.88)	4.1 ^b (16.31)	9.54 ^b (90.05)	20.72 ^b (228.8)
T ₄	8.11 ^{ab} (65.17)	1.18 ^b (0.89)	9.29 ^b (85.70)	6.92 ^b (47.38)	3.62 ^b (12.60)	5.60 ^c (30.86)	16.14 ^d (259.9)
T ₅	6.49 ^b (41.62)	1.96 ^b (3.34)	8.45 ^b (70.90)	6.55 ^b (42.40)	3.63 ^b (12.61)	6.41 ^c (40.58)	16.59 ^{cd} (274.7)
T ₆	11.16 ^a (124.04)	4.01 ^a (15.58)	15.17 ^a (229.7)	11.78 ^a (138.26)	6.63 ^a (43.45)	11.71 ^a (136.6)	30.12 ^a (906.7)
T ₇	7.85 ^{ab} (61.12)	2.07 ^b (3.78)	9.93 ^b (98.10)	6.91 ^b (47.24)	3.43 ^b (11.26)	5.28 ^c (27.37)	15.62 ^d (243.48)
T ₈	5.72 ^b (32.20)	2.17 ^{ab} (4.20)	7.89 ^b (61.75)	5.44 ^b (29.09)	3.31 ^b (10.45)	5.49 ^c (29.64)	14.24 ^d (202.27)
T ₉	4.92 ^b (23.70)	2.01 ^b (3.54)	6.94 ^b (47.66)	5.53 ^b (30.08)	2.86 ^b (7.67)	5.68 ^c (31.76)	14.07 ^d (197.46)
SEM±	0.81	0.53	0.99	0.73	0.43	0.52	1.08
CD (<i>p</i> =0.05)	2.90	1.91	3.54	2.62	1.53	1.86	3.85

Data were subjected to square root $\sqrt{(x+0.5)}$ transformation. Figures in parentheses are original values. Means followed by same letters are not significantly different. DAA, Days after herbicide application; BLWs, Broad-leaved weeds. Refer to Methodology for treatment details.

Table 3 Effect of pre-emergence herbicide mixtures on growth attributes at 60 DAT, yield attributes, yield and economic analysis

Treatment	Plant height (cm)	No. of tillers/m ²	LAI	SPAD reading	Dry matter accumulation (g/m ²)	Effective tiller/m ²	Panicle weight (g)	Filled grain/panicle	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Net return (₹/ha)	BC ratio
60 DAT													
T ₁	80.67 ^{ab}	361 ^{ab}	6.65 ^{bc}	36.63 ^{abc}	18.17 ^c	328 ^b	2.46 ^{ab}	143.6 ^{abc}	16.8 ^{abc}	5,142 ^{ab}	6,083 ^c	84,901 ^e	3.63 ^{bc}
T ₂	84.3 ^{ab}	364 ^{ab}	6.39 ^{bc}	35.67 ^{bc}	18.40 ^c	353 ^{ab}	2.42 ^{ab}	137.0 ^{abc}	14.76 ^c	4,979 ^b	6,037 ^c	81,034 ^f	3.48 ^{cd}
T ₃	78.67 ^b	351 ^b	6.40 ^{bc}	36.75 ^{abc}	17.56 ^c	353 ^{ab}	2.20 ^b	127.3 ^{bc}	17.57 ^{ab}	5,301 ^a	6,274 ^{abc}	87,102 ^c	3.60 ^{bc}
T ₄	81.0 ^{ab}	352 ^{ab}	7.17 ^{abc}	36.13 ^{abc}	22.1 ^{abc}	353 ^{ab}	3.21 ^a	158.6 ^{ab}	15.87 ^{bc}	5,191 ^{ab}	6,165 ^{bc}	85,591 ^{de}	3.62 ^{bc}
T ₅	83.00 ^{ab}	365 ^{ab}	7.29 ^{abc}	36.38 ^{abc}	23.5 ^{ab}	364 ^{ab}	2.79 ^{ab}	124.6 ^c	17.67 ^{ab}	5,241 ^{ab}	6,240 ^{abc}	86,594 ^{cd}	3.66 ^b
T ₆	78.45 ^b	347 ^b	6.17 ^c	34.30 ^c	21.3 ^{abc}	308 ^b	2.94 ^{ab}	116.3 ^c	16.21 ^{bc}	4,597 ^c	6,026 ^c	74,568 ^g	3.38 ^d
T ₇	85.00 ^{ab}	366 ^{ab}	7.39 ^{abc}	36.10 ^{abc}	18.8 ^{bc}	357 ^{ab}	3.21 ^a	148 ^{abc}	15.30 ^{bc}	5,212 ^{ab}	6,236 ^{abc}	85,835 ^{cde}	3.60 ^{bc}
T ₈	87.00 ^a	370 ^{ab}	8.18 ^a	38.12 ^{ab}	24.25 ^a	410 ^a	3.31 ^a	164 ^a	18.75 ^a	5,400 ^a	6,345 ^{ab}	89,333 ^b	3.64 ^{bc}
T ₉	85.00 ^{ab}	382 ^a	7.73 ^{ab}	38.86 ^a	23.6 ^{ab}	413 ^a	3.3 ^a	168.6 ^a	19.01 ^a	5,413 ^a	6,323 ^a	90,944 ^a	3.83 ^a
SEM±	1.90	8.66	0.39	0.87	1.39	20.60	0.28	9.26	0.70	79	73	366	0.04
CD (<i>p</i> =0.05)	6.77	30.80	1.3	3.1	4.95	73.29	1.00	32.93	2.49	283	260	1,303	0.17

Data were subjected to square root $\sqrt{(x+0.5)}$ transformation. Figures in parentheses are original values. Means followed by same letters are not significantly different. DAT, Days after transplanting; LAI, Leaf area index; SPAD, Soil plant analysis development; BC ratio, Benefit-cost ratio. Refer to Methodology for treatment details.

Table 4 Effect of pre-emergence herbicide mixtures on phytotoxicity symptoms on rice

Treatment	Phytotoxicity rating		
	7 DAA	14 DAA	21 DAA
T ₁	1	0	0
T ₂	1	0	0
T ₃	0	0	0
T ₄	1	0	0
T ₅	0	0	0
T ₆	0	0	0
T ₇	1	1	0
T ₈	2	1	0
T ₉	3	2	0

Crop phytotoxicity level: 0–1, None; 1–3, Slight; 4–6, Moderate; 7–9, Severe; 10, Complete. DAA, Days after herbicide application. Refer to Methodology for treatment details.

of effective tillers (413/m²), panicle weight (3.3 g), number of filled grains/panicle (168) and test weight (19.01 g) followed by metsulfuron methyl + chlorimuron ethyl + pretilachlor @1,508 g a.i./ha (T₈) (Table 3). Pretilachlor as chloroacetamide group inhibits cell division and oxidiazon might control weeds by inhibiting an essential plant growth enzyme known as protoporphyrinogen oxidase and this inhibition hinders the usual developmental functions of the weeds and breaks down tissues.

Yield: Treatment T₉ recorded highest grain yield (5.41 t/ha) due to the significantly highest yield attributes of transplanted rice while T₈ recorded the highest straw yield (6.35 t/ha) (Table 3).

Economics: Oxidiazon + pretilachlor @520 + 150 mL a.i./ha (T₉) recorded the significantly highest net return (₹90,944/ha) which was at par with T₈. Treatment T₉ also recorded maximum BC ratio (3.83) which was at par with T₅ as compared to other pre-emergence herbicides mixtures whereas lowest net return and BC ratio was found in weedy check due to highest competition with different weeds resulting in lowest yield (Table 3).

Phytotoxicity level in rice: At 7 and 14 DAA, treatment T₉ recorded slight to moderate phytotoxicity symptoms from 3 DAA with yellowing, stunting, necrosis, epinasty and hyponasty followed by T₈ as compared to other pre-emergence herbicide mixtures (Table 4). Crop gradually recovered from phytotoxicity symptoms at 21 DAA. Shahabuddin *et al.* (2016) also reported that pretilachlor caused yellowing of leaf tip and oxadiazon caused browning to leaf of rice. In both cases crop recovered within two weeks of application without affecting crop growth.

SUMMARY

A field experiment was conducted to evaluate the bio-efficacy and phytotoxicity of pre-emergence herbicide mixtures on weed growth and yield in transplanted rice (*Oryza sativa* L.) cv. 'Samba Mahsuri' (BPT-5204) during *kharif*

2023 with nine treatments replicated thrice at the Agricultural Research Farm, Banaras Hindu University, Varanasi, Uttar Pradesh. The weed flora in the trial comprised of grasses (*Cynodon dactylon*, *Echinochloa colona*, *Paspalum distichum*), sedges (*Cyperus rotundus*, *Fimbristylis miliacea*, *Cyperus difformis*), and broad-leaved weeds (*Ipomoea aquatica*, *Sagittaria guayanensis*, *Marsilea quadrifolia*, *Eclipta prostrata*, *Rotala densiflora*). Among all the treatments, oxidiazon + pretilachlor @520 + 150 mL a.i./ha (T₉) recorded significantly lowest weed density (355 weeds/m²) and weed dry weight (197.46 g/m²) at 60 DAA. It also recorded significantly highest yield attributes, effective tillers, panicle weight, filled grains/panicle and test weight resulting in the highest grain yield, net return and BC ratio with slight to moderate phytotoxicity symptoms at 7 and 14 DAA but the crop recovered completely by 21 days without any lasting effect on growth or productivity. It also registered lowest weed density and weed dry weight, highest yield attributes viz., effective tillers (413/m²), panicle weight (3.3 g), filled grains/panicle (168) and test weight (19.01 g), resulting in the highest grain yield (5.41 t/ha), net return (₹90,944/ha) and benefit-cost ratio (3.83) in transplanted rice. It may, therefore, be concluded that application of oxidiazon + pretilachlor @520 + 150 mL a.i./ha can be recommended as an effective and economically viable pre-emergence herbicide mixture for weed management in transplanted rice under the agro-climatic conditions of Varanasi region.

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