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Weed Dynamics as Influenced by Pre-Emergence Herbicides Combinations in Direct Seeded Rice (*Oryza sativa* L.)

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Abstract

A field experiment was conducted during *kharif* 2021 at College of Agriculture, V.C. Farm, Mandya to study the effect of pre-emergence herbicides on growth and yield of direct seeded rice (*Oryza sativa* L.). The experiment was laid out in RCBD with three replications consisting of nine treatments *viz*., pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG (Pre mix) @ 1500, 2000, 2500 g ha^{-1}, respectively, pyrazosulfuron ethyl 10% WP @ 250 g ha^{-1}, pretilachlor 50% EC @ 1500 ml ha^{-1}, pretilachlor 30% EC + 10% safener @ 1000 ml ha^{-1}, hand weeding (20 & 40 DAS), weed free check and weedy check. The predominant weed flora observed were *Echinochloa colona*, *Cynodon dactylon*, *Eleusine indica, Dinebra retroflexa, Dactyloctenium aegyptium*, *Chloris barbata, Physalis minima*, *Ageratum conyzoides*, *Portulaca olearacea*, *Parthenium hysterophorus*, *Gomphrena decumbens*, *Cyperus rotundus* and *Cyperus iria*. The results revealed that pre-emergence application of pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG (Pre mix) @ 2500 g ha^{-1} at 3 DAS recorded significantly lower total weed count (0.25, 0.72,15.00 and 19.33 No. m^{-2}), weed dry weight (1.22, 3.09, 5.50 and 8.08 g m^{-2}) and weed control efficiency of 84.36, 82.86, 79.00 and 78.82 per cent, respectively at 15, 30, 60 DASP and at harvest. Due to efficient weed control the same treatment recorded high nutrient uptake by the crop (84.42, 43.90 and 63.47 NPK kg ha^{-1}), net monetary returns (Rs.92120 ha^{-1}) and B: C ratio (3.54) and was statistically comparable with weed free check.

Keywords : Pretilachlor, Pyrazosulfuron ethyl, Pre-emergence, Direct seeded rice

Rice (*Oryza sativa* L.) is one of the important cereal crop of the world. It is the primary food source for more than one third of the world's population. It is predominantly grown by transplanting seedlings but this practice consumes about 150 ha-cm of water and engages labour for transplanting and weeding. Manual transplanting is labour cumbersome and scarcity of labour during peak season force to shift the crop establishment methods from transplanting to direct-seeded rice (DSR) (Choudhary and Dixit, 2018). DSR offers several advantages like ease in sowing, less water and labour requirement, high water use efficiency, less greenhouse gas emission and early maturation by 7-10 days over transplanted conditions (Roy, 2016). However, weeds are the major biological constraint in DSR mainly due to absence of impounding of water at crop emergence and emergence of weed and crop at the same time. Hence, weed management is very crucial for increasing the yield of rice in DSR.

Manual weeding is one of the best method but due to labour scarcity and increasing wages, the fields are left un-weeded at critical growth stages of the crop.

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In this condition, herbicides are an alternative to hand weeding in DSR rice. Use of pre-emergence herbicides in DSR will prevent the simultaneous emergence of weeds with rice crop during early stages, though the application window is narrow for pre-emergence herbicides. However, the efficacy of pre-emergence herbicides can vary from molecule to molecule and the operating environmental condition.. Therefore, the study was carried out to find effective herbicides which are economically feasible for weed control and for realizing higher productivity and profitability in direct seeded rice.

Material and Methods

A field experiment was conducted in College of Agriculture, V.C. Farm, Mandya, Karnataka (12°45' North latitude, 76°45' East longitude and 695 m above mean sea level) under Southern Dry Zone. The soil of the experimental site was sandy clay loam with alkaline pH (8.02), electrical conductivity of 0.38 dS m^{-1} and organic carbon content was 0.51 per cent. The soil is low in available nitrogen content, medium in available phosphorus and potassium content. The experiment on dry direct seeded rice was laid out in RCBD with nine treatments replicated thrice and treatments included pre-emergence application of pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG (Pre mix) @ 1500, 2000 and 2500 g ha^{-1} at 0-3 DAS, pyrazosulfuron ethyl 10% WP @ 250 g ha^{-1} at 3-5 DAS, pretilachlor 50% EC @ 1500 ml ha^{-1} at 0-5 DAS, pretilachlor 30% EC + 10% safener @ 1000 ml ha^{-1} at 3-5 DAS, hand weeding (20 & 40 DAS), weedy check (control), weed free check (Table 1). The crop was sown in the *kharif* season (10th August to 26th December 2021) and received total rainfall of 622.5mm. Variety IR-30864 was sown in line with row spacing of 20 cm in rows and after two weeks of sowing plant to plant spacing was maintained by 10 cm spacing between plants. At the time of sowing recommended dose of fertilizer (100:50:50 kg ha^{-1}) was applied through urea, single super phosphate and muriate of potash. The nitrogen was applied in 3 splits and entire dose of P and K were applied as basal dose.

Grasses, sedges and broad-leaved weeds were counted separately using quadrat of 0.25 m^2 in each net plot at 15, 30, 60 DASP and at harvest. Weed density and weed dry weight was recorded at harvest with the help of 0.25 m^2 quadrat and the data was subjected to square root transformation ($\sqrt{x+0.5}$) to normalize the distribution as suggested by Gomez and Gomez (1984). The weed control efficiency was worked out based on the data from weed dry weight using the formula suggested by Mani *et al*. (1973). The nutrient uptake by the crop and the weeds were analysed after harvest of the crop. Panicles per meter of row length, panicle weight from randomly selected tagged plants were counted and averaged. On the basis of grain weight per plot, the grain yield per hectare was calculated and expressed in kg ha^{-1}. Weed index was worked out by using the grain yield of various treatments. The data obtained were subjected to statistical analysis by analysis of variance (ANOVA) to test the significance of the over all differences among the treatments by the "F" test and conclusions were drawn at 5 per cent probability level. The economic feasibility of the treatments was worked out keeping in view of the cost of herbicides and current selling price of the produce.

$$\text{WCE (\%)} = \frac{\text{Dry weight of weeds in control plot - Dry weight of weeds in treated ploting}}{\text{Dry weight of weeds in control plot}} \times 100$$

$$\text{Weed index (\%)} = \frac{\text{Grain yield from weed free plot - Grain yield of treatment plot for which weed index needs to be calculated}}{\text{Grain yield from weed free plot}} \times 100$$

Results and Discussion

Weed Flora

The most common weed flora observed in the experimental field were, *Echinochloa colona* (barnyard grass), *Cynodon dactylon* (bermuda grass), *Eleusine indica, Dinebra retroflexa, Dactyloctenium aegyptium, Panicum repens* (quack grass), *Chloris*

TABLE 1

Effect of pre- emergence herbicides on weed density (no. m^{-2}) in direct seeded rice at 15 and 30 days after spraying

Treatment	15 DASP				30 DASP			
	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total
T_1	*1.27 (1.10)	1.34 (1.29)	1.63 (2.17)	2.25 (4.56)	1.62 (2.14)	1.41 (1.49)	1.91 (3.17)	2.70 (6.79)
T_2	1.14 (0.80)	0.81 (0.16)	1.24 (1.04)	1.58 (2.00)	1.34 (1.31)	0.88 (0.30)	1.48 (1.71)	1.95 (3.32)
T_3	0.77 (0.09)	0.73 (0.03)	0.79 (0.13)	0.87 (0.25)	0.84 (0.20)	0.83 (0.19)	0.90 (0.32)	1.10 (0.72)
T_4	1.14 (0.81)	0.98 (0.46)	1.38 (1.40)	1.78 (2.67)	1.52 (1.81)	0.98 (0.47)	1.60 (2.07)	2.20 (4.35)
T_5	1.22 (0.99)	1.39 (1.44)	1.53 (1.85)	2.19 (4.28)	1.58 (1.99)	1.40 (1.45)	1.83 (2.85)	2.61 (6.29)
T_6	1.22 (0.99)	1.35 (1.33)	1.51 (1.78)	2.14 (4.10)	1.58 (1.99)	1.35 (1.34)	1.81 (2.78)	2.57 (6.10)
T_7	0.71 (0.01)	0.71 (0.00)	0.78 (0.11)	0.79 (0.12)	0.76 (0.08)	0.76 (0.08)	0.79 (0.12)	0.89 (0.28)
T_8	2.30 (4.81)	1.71 (2.43)	2.07 (3.80)	3.40(11.05)	2.49 (5.68)	1.75 (2.57)	2.25 (4.59)	3.65(12.84)
T_9	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
S.Em±	0.04	0.02	0.03	0.03	0.04	0.03	0.05	0.03
C.D (P=0.05)	0.11	0.06	0.10	0.10	0.12	0.10	0.14	0.08

DASP – Days after spraying * Transformed values [$\sqrt{(x+0.5)}$], Values in the parenthesis indicates original values

T_1 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 1500 g ha^{-1} at 0-3 DAS

T_2 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2000 g ha^{-1} at 0-3 DAS

T_3 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS

T_4 – Pyrazosulfuron ethyl 10% WP @ 250 g ha^{-1} at 3-5 DAS

T_5 – Pretilachlor 50% EC @ 1500 ml ha^{-1} at 0-5 DAS

T_6 – Pretilachlor 30% EC + 10% safener @ 1000 ml ha^{-1} at 3-5 DAS

T_7 – Hand weeding (20 & 40 DAS)

T_8 – Weedy check (control)

T_9 – Weed free check

TABLE 2

Effect of pre- emergence herbicides on weed density (no. m^{-2}) in direct seeded rice at 60 days after spraying and at harvest

Treatment	60 DASP				At harvest			
	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total
T_1	*3.24 (10.00)	1.96 (3.33)	3.91 (14.83)	5.35 (28.17)	3.81 (14.00)	2.23 (4.50)	3.67 (13.00)	5.65 (31.50)
T_2	2.80 (7.33)	1.68 (2.33)	3.08 (9.00)	4.38 (18.67)	3.02 (9.00)	2.12 (4.00)	3.02 (8.67)	4.67 (21.33)
T_3	2.35 (5.33)	1.47 (1.67)	2.91 (8.00)	3.92 (15.00)	2.90 (10.00)	1.96 (3.33)	2.91 (8.00)	4.45 (19.33)
T_4	3.03 (8.67)	1.78 (2.67)	3.61 (12.67)	4.94 (24.00)	3.53 (12.00)	2.20 (4.33)	3.23 (10.00)	5.18 (26.33)
T_5	3.18 (9.60)	1.87 (3.00)	3.94 (15.00)	5.30 (27.60)	3.89 (14.00)	2.34 (5.00)	3.53 (12.00)	5.67 (31.62)
T_6	3.08 (9.00)	1.82 (2.83)	3.89 (14.67)	5.20 (26.50)	3.72 (15.00)	2.27 (4.67)	3.39 (11.00)	5.43 (29.00)
T_7	1.93 (3.33)	1.34 (1.30)	2.59 (6.33)	3.37 (10.97)	2.72 (5.00)	1.78 (2.67)	2.85 (7.67)	4.21 (17.33)
T_8	5.49 (29.67)	2.86 (7.67)	5.81 (33.33)	8.43 (70.67)	5.87 (34.00)	3.24 (10.00)	6.28 (39.00)	9.14 (83.00)
T_9	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
S.Em±	0.16	0.05	0.12	0.12	0.13	0.06	0.12	0.12
C.D (P=0.05)	0.48	0.15	0.37	0.35	0.39	0.19	0.35	0.35

DASP – Days after spraying * Transformed values [$\sqrt{(x+0.5)}$], Values in the parenthesis indicates original values

T_1 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 1500 g ha^{-1} at 0-3 DAS

T_2 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2000 g ha^{-1} at 0-3 DAS

T_3 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS

T_4 – Pyrazosulfuron ethyl 10% WP @ 250 g ha^{-1} at 3-5 DAS

T_5 – Pretilachlor 50% EC @ 1500 ml ha^{-1} at 0-5 DAS

T_6 – Pretilachlor 30% EC + 10% safener @ 1000 ml ha^{-1} at 3-5 DAS

T_7 – Hand weeding (20 & 40 DAS)

T_8 – Weedy check (control)

T_9 – Weed free check

barbata among grassy weeds. Among broad leaved weeds, *Physalis minima* (native gooseberry), *Ageratum conyzoides* (billygoat weed), *Portulaca olearacea* (common purslane), *Parthenium hysterophorus* (congress grass), *Sida spinosa*, *Ipomoea aquatica, Marsilea quadrifolia, Acmella paniculata* and among the sedges, *Cyperus rotundus* (purple nut sedge), *Cyperus iria* and *Fimbristylis miliacea* were observed.

Weed Density and Weed Dry Weight

The effect of different herbicides on total weed density, weed dry weight and weed control efficiency in direct seeded rice are presented in Table 1, 2 and 3. Significantly lower total weed density in all the stages of direct seeded rice and lower weed dry weight (7.02 g m) at harvest were observed in the treatment containing hand weeding (20 & 40 DAS), due to effectiveness of hand weeding to eliminate both above and below ground parts of weeds from direct seeded rice, which inturn reduced the weed density and weed dry weight. Due to the efficiency of hand weeding in eradicating all types of weeds, hand weeding recorded low weed dry weight and high weed control efficiency (81.62%). Findings are in conformity with Awotundum (2004), Saha *et al*. (2005) and Arthanari *et al*. (2012).

Among herbicidal treatments, pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG (Pre mix) @ 2500 g ha^{-1} at 0-3 DAS recorded significantly lower total weed density during all the stages of direct seeded rice. Moreover lower weed count of grasses, sedges and broad leaved weeds were observed in this treatment. Thus the herbicidal combinations was

TABLE 3

Effect of pre- emergence herbicides on weed dry weight (g m^{-2}) and WCE in direct seeded rice at different growth stages

Treatment	Weed dry weight (g m^{-2})				Weed control efficiency (%)			
	15 DASP	30 DASP	60 DASP	At harvest	15 DASP	30 DASP	60 DASP	At harvest
T_1 – Pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG @ 1500 g ha^{-1} at 0-3 DAS	*2.11 (3.95)	2.93 (8.09)	4.00 (15.50)	5.07 (25.24)	49.22	55.01	40.63	33.93
T_2 – Pretilachlor 30% EC + pyrazosulfuronethyl 0.75% WG @ 2000 g ha^{-1} at 0-3 DAS	1.61 (2.11)	2.32 (4.90)	2.93 (8.10)	3.63 (12.70)	72.90	72.78	68.91	66.80
T_3 – Pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS	1.31 (1.22)	1.89 (3.09)	2.45 (5.50)	2.93 (8.08)	84.36	82.86	79.00	78.82
T_4 – Pyrazosulfuron ethyl 10% WP @ 250 g ha^{-1} at 3-5 DAS	1.70 (2.40)	2.52 (5.89)	3.54 (12.05)	4.33 (18.23)	69.11	67.28	53.95	52.26
T_5 – Pretilachlor 50% EC @ 1500 ml ha^{-1} at 0-5 DAS	1.82 (2.80)	2.68 (6.67)	3.79 (13.86)	4.73 (21.91)	64.11	62.93	46.94	42.59
T_6 – Pretilachlor 30% EC + 10% safener @ 1000 ml ha^{-1} at 3-5 DAS	1.80 (2.76)	2.62 (6.40)	3.68 (13.05)	4.49 (19.66)	64.45	64.41	50.09	48.56
T_7 – Hand weeding (20 & 40 DAS)	0.71 (0.00)	1.13 (0.78)	2.28 (4.73)	2.74 (7.02)	100.00	95.64	82.09	81.62
T_8 – Weedy check (control)	2.88 (7.79)	4.30(17.98)	5.16 (26.19)	6.22 (38.25)	-	-	-	-
T_9 – Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	-	-	-	-
S.Em±	0.09	0.05	0.07	0.04	-	-	-	-
C.D @ 5%	0.26	0.14	0.22	0.13	-	-	-	-

DASP – Days after spraying; * Transformed values [√(x+0.5)], Values in the parenthesis indicates original values

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TABLE 4

Effect of pre-emergence herbicides on uptake of major nutrients by the crop at harvest in direct seeded rice

Treatment	Nutrient uptake by crop			Nutrient uptake by weeds		
	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	64.77	35.37	51.12	14.23	11.59	11.94
T_2	81.20	40.22	60.69	9.82	6.71	7.51
T_3	84.42	43.90	63.47	8.21	3.84	5.55
T_4	78.30	38.56	56.46	11.73	8.49	9.37
T_5	69.85	35.54	51.34	14.16	11.40	11.76
T_6	74.69	36.19	54.80	13.72	11.10	11.11
T_7	86.93	46.96	68.80	5.65	2.86	4.67
T_8	15.44	9.19	10.51	29.62	15.87	34.33
T_9	97.36	50.80	75.26	0.00	0.00	0.00
S.Em±	3.19	2.27	2.46	0.67	0.32	0.34
C.D @ 5%	9.56	6.81	7.38	2.00	0.95	1.02

T_1 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 1500 g ha^{-1} at 0-3 DAS
T_2 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2000 g ha^{-1} at 0-3 DAS
T_3 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS
T_4 – Pyrazosulfuron ethyl 10% WP @ 250 g ha^{-1} at 3-5 DAS
T_5 – Pretilachlor 50% EC @ 1500 ml ha^{-1} at 0-5 DAS
T_6 – Pretilachlor 30% EC + 10% safener @ 1000 ml ha^{-1} at 3-5 DAS
T_7 – Hand weeding (20 & 40 DAS)
T_8 – Weedy check (control)
T_9 – Weed free check

TABLE 5

Effect of pre-emergence herbicides on yield attributes at harvest in direct seeded rice

Treatment	Panicles per m row length	Panicle weight (g)	Panicle length (cm)	Chaffiness (%)	Test weight (g)
T_1 – Pretilachlor 30% EC + pyrazosulfuron ethyl 0.75% WG @ 1500 g ha^{-1} at 0-3 DAS	82.30	1.63	18.57	13.59	26.74
T_2 – Pretilachlor 30% EC + pyrazosulfuronethyl 0.75% WG @ 2000 g ha^{-1} at 0-3 DAS	86.4	2.02	19.46	11.07	28.14
T_3 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS	93.8	2.66	19.78	10.02	29.10
T_4 - Pyrazosulfuron ethyl 10% WP @ 250 g ha^{-1} at 3- 5 DAS	85.8	1.86	18.83	12.73	27.16
T_5 – Pretilachlor 50% EC @ 1500 ml ha^{-1} at 0-5 DAS	85.4	1.67	18.53	13.40	26.60
T_6 – Pretilachlor 30% EC + 10% safener @ 1000 ml ha^{-1} at 3-5 DAS	85.7	1.69	18.66	12.82	27.13
T_7 – Hand weeding (20 & 40 DAS)	94.1	2.71	20.50	9.75	29.13
T_8 – Weedy check (control)	56.7	0.82	16.90	39.86	23.84
T_9 – Weed free check	101.3	2.92	21.37	6.74	30.98
S.Em±	2.66	0.09	0.62	0.56	0.68
C.D @ 5%	7.97	0.27	1.85	1.68	2.04

highly effective in controlling the weeds. The earlier research findings on pre-emergence herbicides used in combinations have also shown to effectively suppress weeds at an early stage with low weed dry weight. In addition, in these treatments, weeds were inhibited by the high crop canopy. Due to higher competition for resources with crop plants, the weed density was higher in weedy check. Similar findings were reported from Mondal *et al*. (2019) and Ramesha *et al*. (2019).

Nutrient Uptake by Crop and Weeds

All the weed management techniques, in general, have led to high nutrient uptake by crop than weedy check (Table 4). Among the herbicidal treatments, pretilachlor 30% EC+ pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS recorded high nutrient uptake by the crop due to increased dry matter production, vigorous crop growth and the efficiency of weed management techniques in reducing weed competition for nutrients. These results are in similarity with Kumari (1991), Sahai and Bhan (1992) and Singh *et al*. (2005).

Nutrient removal (NPK) in weeds was higher in the unweeded control, mostly as a result of larger weed biomass and weed population, which allowed weeds to absorb most of the nutrients. The crop weed competition for NPK increased in proportion to the weed infestation, which led to higher uptake. The results are in conformity with that of Kumari (1991), Geetha (2002), Singh *et al*. (2005) and Islam and Kalita (2014).

Yield Attributes

Yield attributes were significantly influenced by the application of different pre-emergence herbicides (Table 5). Results obtained revealed that significantly high yield attributes *viz*., panicles per meter row length, panicle weight (2.92g), panicle length (19.78 cm), chaffiness percentage (10.02 %), test weight (29.10 g) were recorded in weed free check. Among the herbicidal treatments, pretilachlor 30% EC+ pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS recorded significantly higher yield attributes and was on par with hand weeding (20 & 40 DAS). Among the herbicides, pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS recorded higher grain yield primarily due to effective management of weeds *viz.,* grasses, sedges and broad-leaved weeds present during the crop growing period, which might have led to less competition for nutrients,

Table 6

Economics of direct seeded rice as influenced by pre-emergence herbicides in direct seeded rice

Treatment	Grossreturns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C ratio
T_1 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 1500 g ha^{-1} at 0-3 DAS	90835	35401	55434	2.57
T_2 – Pretilachlor 30% + pyrazosulfuronethyl 0.75% WG @ 2000 g ha^{-1} at 0-3 DAS	108706	35180	73526	3.09
T_3 – Pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS	128339	36219	92120	3.54
T_4 – Pyrazosulfuron ethyl 10% WP @ 250 g ha^{-1} at 3- 5 DAS	94681	34800	59881	2.72
T_5 – Pretilachlor 50% EC @ 1500 ml ha^{-1} at 0-5 DAS	94043	35168	58875	2.67
T_6 – Pretilachlor 30% EC + 10% safener @ 1000 ml ha^{-1} at 3-5 DAS	93973	35839	58134	2.62
T_7 – Hand weeding (20 & 40 DAS)	129392	46375	83017	2.79
T_8 – Weedy check (control)	56633	34175	22458	1.66
T_9 – Weed free check	136880	70776	66104	1.93

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increased rice photosynthetic activity due to more light interception and improved growth parameters, that resulted in higher grain yield. These findings are in agreement with those of Choudhary and Dixit (2018), Ramesha *et al*. (2019) and Nagarjun *et al.* (2022).

Economics

The economics of different herbicides used in direct seeded rice are presented in Table 6. Among different treatments, higher cost of cultivation (Rs.70,776 ha^{-1}) was obtained in weed free check due to high labour wages for weeding and with benefit of higher yield, the same treatment recorded higher gross returns (Rs.1,36,880 ha^{-1}). Whereas, higher benefit-cost ratio of 3.54 was obtained with pretilachlor 30% EC+ pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS because of the favourable growing conditions for crop which further resulted in reduced weed competition, enhanced yield and yield attributing traits. Similar reports have been reported by Upasani and Barla (2014), Arya and Ameena (2016) and Mondal *et al.* (2019).

In direct seeded rice, the initial 45 DAS should be considered most critical to avoid crop weed competetion. Based on the present study, application of pretilachlor 30% + pyrazosulfuron ethyl 0.75% WG @ 2500 g ha^{-1} at 0-3 DAS as pre-emergence herbicide was found to be best in controlling weeds along with obtaining higher weed control efficiency, yield and economic benefit in direct seeded rice.

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