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Efficacy of pyribenzoxim herbicide in dry direct-seeded rice

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ABSTRACT

A study was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during *Kharif* 2017 and 2018 to evaluate the efficacy of pyribenzoxim herbicide in dry direct-seeded rice. Among the herbicidal treatments, pyribenzoxim 5% EC 60 g/ha was the most suitable for controlling weeds, followed by oxadiargyl 80% WP 100 g/ha, though hand weeding treatment showed lowest weed infestation and maximum grain yield (4.55 t/ha). Weed density and weed dry weight had strong negative correlation with grain yield ($r = -0.982^{**}$ and -0.983^{**}, respectively). Total weed population and biomass was the lowest in manually weeded plots followed by pyribenzoxim 5% EC 60 g/ha. The highest weed control efficiency (70.0, 86.7 and 88.3% at 30, 45 and 60 DAS, respectively), weed control index (82.9, 85.5 and 86.4% at 30, 45 and 60 DAS, respectively) and herbicide efficiency index (43.4%) were found with pyribenzoxim 5% EC 60 g/ha. The pyribenzoxim 5% EC 60 g/ha at 15 DAS was found the most remunerative with benefit-cost ratio of 2.42.

INTRODUCTION

Rice (*Oryza sativa* L.) plays a significant role in the economy of India and occupies central position in national agricultural policy and food security. Direct-seeded rice (DSR) is gaining popularity as an alternative to puddled transplanted rice. It allows early establishment of the succeeding wheat crop and ensures higher profit in areas with assured water supply. Weed infestation is however one of the limiting factors in DSR. The yield losses due to weeds are greater in DSR than the transplanted rice in the absence of effective weed control options (Singh *et al.* 2018). Generally pre-emergence herbicides like pretilachlor, butachlor, anilophos and post-emergence herbicides like 2,4-D, bispyribac-sodium and metsulfuron-methyl + chlorimuron-ethyl are being used frequently for broad-spectrum weed control in DSR. Continuous application of same herbicide also results in weed flora shift and development of herbicide resistance in weeds. Hence, there is always a need to develop and evaluate alternate herbicides to overcome these problems. Keeping in view the above constraints, a field experiment was undertaken to study the efficacy of a new post-emergence herbicide 'pyribenzoxim' in DSR for broad-spectrum weed control.

MATERIALS AND METHODS

The field experiment was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during *Kharif* 2017 and 2018. During the crop growing period, minimum and maximum temperature varied between 12.2^{0}C and 33.8^{0}C and the total rainfall was 850.5 mm. The experimental soil (0-15 cm soil layer) was sandy loam in texture with pH 6.83, organic carbon (C) 0.79%, mineralizable nitrogen (N) 180.29 kg/ha, phosphorus (P) 19.50 kg/ha and NH_4OAc extractable potassium (K) 169.10 kg/ha. Eight weed management treatments comprised of pyribenzoxim 5% EC 25 g/ha, pyribenzoxim 5% EC 30 g/ha, pyribenzoxim 5% EC 35 g/ha, pyribenzoxim 5% EC 60 g/ha, fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha, oxadiargyl 80% WP 100 g/ha, hand weeding and weedy check were replicated thrice in a randomized block design (RBD). The size of each plot was 5.25 × 3.60 m. Herbicides were sprayed as post-emergence at 15 days after sowing (DAS) *i.e.*, 2-3 leaf stage of rice. Hand weeding was done twice at 20 and 40 DAS. Dry DSR was practiced under rice-wheat cropping system with an early maturing (110-115 days) rice variety '*MTU 1010*' which is suitable for cultivation

in Madhya Pradesh. Sowing of seeds was done in rows 20 cm apart with a seed-cum-fertilizer drill in an unpuddled field on 4th July during both the years. A fertilizer dose of 120:60:40 kg/ha N:P:K, and seed rate of 60 kg/ha was used. Half dose of N, full dose of P and K was applied as basal at the time of sowing, one-fourth of N was top-dressed during active tillering (30-45 DAS) and remaining one-fourth of N was top-dressed at panicle initiation stage (60 DAS). The crop was irrigated twice just before N top-dressing.

Weed control efficiency (WCE) and weed control index (WCI) were worked out by the formulas suggested by Das (2013).

Herbicide efficiency index (HEI) was calculated based on the weed killing potential of different herbicide treatments as per formula (Krishnamurthy *et al.* 1995):

$$\text{HEI (\%)} = \frac{\text{Yield in treatment plot-yield in control plot}}{\text{Yield in control plot}} \times 100$$

Gross returns, net returns and benefit-cost (B:C) ratio were calculated by taking market price of rice grain (₹ 14.50/kg in 2017 and ₹ 15.50/kg in 2018) and rice straw (₹ 1.00/kg in 2017 and 2018). All the data were analyzed by analysis of variance (ANOVA) method with SPSS software. The differences between treatment means were tested at the significance level of 5%.

RESULTS AND DISCUSSION

Dominant weed flora in DSR

The dominant weed flora observed at the experimental field contained *Echinochloa colona* (barnyard grass), *Digitaria sanguinalis* (large crab grass), *Alternanthera sessilis* (khaki weed), *Physalis minima* (ground cherry), *Cyperus rotundus* (purple nut sedge) and *Cyperus iria* (flat sedge). Among these weeds, *D. sanguinalis* was the most dominant at 60 DAS during the first year and *A. sessilis* during the second year. Pandey *et al.* (2010) reported that *A. sessilis* was one of the most pre-dominant broad-leaved weed species in DSR in Jabalpur, Madhya Pradesh. *C. rotundus* was more rampant than *C. iria* due to its continuous regrowth during the crop season.

Weed density and weed dry weight

After spraying of herbicides, weed density was the highest in weedy check at 15, 30 and 45 days after herbicide application (DAA) and the lowest in hand weeded plots followed by pyribenzoxim 5% EC 60 g/ha. Application of pyribenzoxim 5% EC 60 g/ha lowered the weed population by 54.8, 58.8 and 60.2% for grasses, 26.2, 66.5 and 67.2% for broad-leaved weeds and 61.0, 62.7 and 64.7% for sedges at 15, 30 and 45 DAA, respectively as compared to untreated control **(Table 1)**. Application of pyribenzoxim 5% EC 60 g/ha reduced total weed density by 57 to 85% **(Table 3)**. This result was in accordance with the report of Gu *et al.* (2006). Hand weeding witnessed the lowest weed dry weight followed by the pyribenzoxim 5% EC treated plots where weed dry weight decreased by 53.5, 58.4 and 61.2% for grassy weeds, 57.3, 61.8 and 63.0% for broad-leaved weeds and 60.9, 60.5 and 63.5% for sedges at 15, 30 and 45 DAA, respectively **(Table 2)**. Moon *et al.* (1998) also reported much lower total weed dry weight in pyribenzoxim applied plots than control plots **(Table 3)**. The results also revealed that broad-leaved weeds had the highest dry weight followed by sedges and grasses at 15, 30 and 45 DAA in un-treated plots. Among all the herbicidal treatments, the lowest weed dry weight was recorded with pyribenzoxim 5% EC 60 g/ha. Hand weeding twice at 20 and 40 DAS had the lowest weed density and dry weight. Post-emergence application of fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha resulted in good control on grassy weeds as demonstrated by Singh *et al.* (2016) and sedges, by reducing their population and biomass production but was not effective on broad-leaved weeds.

Weed control efficiency, weed control index, weed index and herbicide efficiency index

Among the herbicides, the highest weed control efficiency (WCE) and weed control index (WCI) were noticed with pyribenzoxim 5% EC 60 g/ha and the lowest in fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha. Similar findings were also observed by Moon *et al.* (1998) and Ma *et al.* (2014). However, oxadiargyl 80% WP 100 g/ha treatment had better weed controlling ability than the lower doses of pyribenzoxim 5% EC **(Table 4)**. Among the chemical weed management options, the lowest weed index (4.8%) was recorded with post-emergence application of pyribenzoxim 5% EC 60 g/ha closely followed by oxadiargyl 80% WP 100 g/ha (6.0%). Lower WI indicated the superiority of these two treatments in higher magnitude of weed suppression with increased grain yield and selectivity to rice. Herbicide efficiency index (HEI) was maximum in foliar application of pyribenzoxim 5% EC 60 g/ha (43.4%) followed by oxadiargyl 80% WP 100 g/ha (41.6%). It was also observed that hand weeding twice at 20 and 40 DAS was superior among all the treatments in reducing weed growth with the highest WCE (79.2%, 95.6% and 97.2% at 30, 45 and 60

Table 1. Effect of different weed management options on density of grasses, broad-leaved weeds and sedges (pooled data of 2 years)

Treatment	Weed density (no./m^2)											
	Grassy weeds				Broad-leaved weeds				Sedge weeds			
	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA
Pyribenzoxim 5% EC 25 g/ha	8.1 (64.8)	4.7 (21.5)	4.7 (20.8)	4.4 (18.7)	8.2 (66.8)	6.4 (39.8)	4.6 (20.0)	4.4 (18.4)	7.8 (59.1)	4.2 (16.4)	4.0 (15.3)	4.0 (14.7)
Pyribenzoxim 5% EC 30 g/ha	8.1 (64.9)	4.5 (19.3)	4.4 (18.5)	4.2 (16.7)	8.4 (70.2)	6.7 (44.1)	4.3 (17.5)	4.2 (16.3)	7.7 (58.5)	3.9 (14.3)	3.8 (13.4)	3.6 (12.0)
Pyribenzoxim 5% EC 35 g/ha	8.1 (65.1)	4.5 (19.1)	4.4 (18.3)	4.2 (16.5)	8.5 (70.4)	6.7 (43.7)	4.3 (17.3)	4.1 (16.0)	7.7 (58.3)	3.9 (14.2)	3.8 (13.3)	3.6 (11.8)
Pyribenzoxim 5% EC 60 g/ha	8.1 (64.8)	3.7 (12.7)	3.6 (11.8)	3.3 (10.4)	8.5 (70.7)	6.3 (38.4)	2.9 (7.7)	2.9 (7.3)	7.7 (58.0)	3.1 (8.6)	3.0 (8.1)	2.9 (7.3)
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	8.1 (64.5)	4.5 (19.0)	4.4 (17.9)	4.2 (16.8)	8.5 (71.2)	8.4 (70.2)	8.5 (72.0)	8.7 (74.9)	7.5 (54.5)	4.1 (15.5)	4.0 (14.7)	3.8 (13.3)
Oxadiargyl 80% WP 100 g/ha	8.1 (65.0)	4.4 (18.3)	4.3 (17.2)	4.1 (15.9)	8.5 (70.3)	6.6 (42.2)	4.2 (16.4)	3.9 (14.1)	7.7 (58.3)	3.8 (13.3)	3.7 (12.9)	3.6 (12.0)
Hand weeding	8.1 (65.2)	2.0 (2.8)	1.9 (2.5)	1.7 (2.0)	8.4 (70.1)	6.2 (36.7)	2.2 (3.8)	1.8 (2.4)	7.8 (59.8)	1.9 (2.5)	1.9 (2.6)	1.6 (1.6)
Weedy check	8.1 (64.8)	8.2 (66.0)	8.3 (67.3)	8.3 (68.5)	8.5 (70.3)	8.6 (72.6)	8.8 (76.0)	8.8 (76.3)	7.8 (59.6)	7.9 (62.0)	8.1 (64.0)	8.2 (66.0)
LSD (p=0.05)	NS	0.78	0.71	0.57	NS	1.06	0.88	0.94	NS	0.81	0.78	0.74

DAA - Days after application; Figures in the parentheses are original values. Data subjected to $(\sqrt{x+1})$ square root transformation

Table 2. Effect of different weed management options on dry weight of grasses, broad-leaved weeds and sedges (pooled data of 2 years)

Treatment	Weed dry weight (g/m^2)											
	Grassy weeds				Broad-leaved weeds				Sedge weeds			
	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA
Pyribenzoxim 5% EC 25 g/ha	5.8 (32.1)	4.0 (14.6)	4.5 (19.2)	4.4 (19.0)	6.1 (36.1)	4.5 (19.3)	4.8 (21.9)	5.0 (23.5)	7.8 (59.1)	3.6 (11.8)	4.1 (15.6)	4.3 (17.7)
Pyribenzoxim 5% EC 30 g/ha	5.8 (32.4)	3.7 (12.6)	4.3 (17.2)	4.2 (16.5)	6.1 (36.2)	4.3 (17.4)	4.5 (19.6)	4.7 (20.8)	7.7 (58.5)	3.4 (10.2)	3.9 (14.0)	4.1 (16.0)
Pyribenzoxim 5% EC 35 g/ha	5.8 (32.6)	3.7 (12.4)	4.2 (16.9)	4.0 (16.3)	6.0 (35.4)	4.3 (17.2)	4.5 (19.3)	4.7 (21.2)	7.7 (58.3)	3.3 (9.9)	3.8 (13.7)	4.1 (15.7)
Pyribenzoxim 5% EC 60 g/ha	5.8 (32.7)	3.0 (8.2)	3.2 (9.5)	3.2 (9.3)	6.1 (35.8)	3.4 (10.3)	3.4 (10.8)	3.5 (11.4)	7.7 (58.0)	2.7 (6.1)	3.1 (8.5)	3.3 (10.1)
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	5.8 (32.9)	3.7 (12.5)	3.4 (10.2)	3.5 (11.3)	6.2 (37.7)	7.6 (56.0)	8.3 (67.0)	9.0 (79.6)	7.7 (58.5)	3.5 (11.2)	4.00 (14.9)	4.2 (16.7)
Oxadiargyl 80% WP 100 g/ha	5.8 (32.3)	3.5 (11.5)	3.8 (13.6)	4.0 (14.8)	6.0 (35.2)	4.0 (14.6)	4.2 (16.6)	4.5 (19.2)	7.7 (58.3)	3.3 (9.9)	3.8 (13.2)	4.0 (15.2)
Hand weeding	5.8 (32.2)	1.6 (1.6)	1.8 (2.1)	1.6 (1.5)	6.0 (34.9)	2.1 (3.3)	2.0 (3.2)	1.9 (2.5)	7.8 (59.8)	1.8 (2.2)	1.9 (2.7)	1.8 (2.1)
Weedy check	5.8 (32.6)	6.5 (40.6)	7.8 (59.5)	8.3 (67.5)	6.0 (35.0)	7.9 (60.7)	9.0 (79.4)	9.5 (89.5)	7.8 (59.6)	6.8 (45.5)	8.0 (62.7)	9.2 (82.6)
LSD (p=0.05)	NS	0.79	0.74	0.72	NS	0.85	0.77	0.83	NS	0.65	0.78	0.80

Figures in the parentheses are original values. Data subjected to $(\sqrt{x+1})$ square root transformation; DAA - Days after application

DAS, respectively), WCI (95.1, 96.0 and 97.4% at 30, 45 and 60 DAS, respectively) and HEI (50.5%).

Growth and yield components and grain yield of direct-seeded rice

The growth components of rice varied significantly with different weed management practices **(Table 5)**. The highest plant height (86.4 cm) at harvest was recorded with hand weeding closely followed by pyribenzoxim 5% EC 60 g/ha (85.1 cm). Untreated control recorded the lowest plant height (71.0 cm) at harvest. At 90 DAS, the maximum number of tillers/m^2 was recorded in hand weeding (303.7) followed by the highest dose of pyribenzoxim 5% EC (285.3). Tiller density was 42.2% higher with foliar application of pyribenzoxim 5% EC 60 g/ha than weedy check. Leaf area index (LAI) was found maximum in hand weeded plots (4.28) followed by pyribenzoxim 5% EC 60 g/ha at 15 DAS (4.19). Due to higher weed infestation, LAI was greatly reduced in un-weeded control (2.90). The highest number of panicles/m^2 at harvest (246.0) was found in manually-weeded condition. Spraying of pyribenzoxim 5% EC 60 g/ha at 2-3 leaf stage of

rice resulted in 48.9% increase in number of panicles/ m^2 at harvest over untreated control, though the highest increment (50.7%) was observed in oxadiargyl 80% WP 100 g/ha **(Table 5)**. Weed controlling treatments provided 25.4-50.2% higher grain yield than weedy check. With the application of pyribenzoxim 5% EC at different doses, the grain yield of rice increased from 30.4-42.9% over weedy check. These results were similar with the report of Gu *et al.* (2006).

Correlation matrix

Weed density and dry weight had significant negative correlation with all the yield components except test weight **(Table 6)**. Number of panicles/m^2, panicle length (cm) and number of filled grains/ panicle had strong significant positive correlation with grain yield of rice (r = 0.990**, 0.887** and 0.895**, respectively). But weed density and dry weight had highly significant negative correlation with grain yield of rice (r = -0.982** and -0.983**,

Table 3. Effect of different weed management options on total density and total dry weight of grasses, broad-leaved weeds and sedges (pooled data of 2 years)

Treatment	Total weed density (no./m^2)				Total weed dry weight (g/m^2)			
	Before spray	15 DAA	30 DAA	45 DAA	Before spray	15 DAA	30 DAA	45 DAA
Pyribenzoxim 5% EC 25 g/ha	8.0(63.6)	5.2(25.9)	4.4(18.7)	4.3(17.2)	6.6(42.9)	4.0(15.2)	4.1(18.9)	4.6(20.0)
Pyribenzoxim 5% EC 30 g/ha	8.1(64.5)	5.2(25.9)	4.2(16.5)	4.0(15.0)	6.6(42.4)	3.8(13.4)	4.2(16.9)	4.3(17.7)
Pyribenzoxim 5% EC 35 g/ha	8.1(64.6)	5.2(25.7)	4.2(16.3)	4.0(14.8)	6.6(42.1)	3.8(13.3)	4.2(16.6)	4.3(17.7)
Pyribenzoxim 5% EC 60 g/ha	8.1(64.5)	4.6(19.9)	3.0(9.2)	3.0(8.2)	6.6(42.1)	3.0(8.1)	3.3(9.6)	3.4(10.6)
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	8.0(63.4)	6.0(34.9)	6.0(34.9)	6.0(35.0)	6.6(43.0)	5.3(26.5)	5.6(30.7)	6.1(35.9)
Oxadiargyl 80% WP 100 g/ha	8.1(64.5)	5.1(24.6)	4.1(15.5)	3.9(14.0)	6.6(41.9)	3.5(12.0)	3.9(14.5)	4.2(16.4)
Hand weeding	8.1(65.0)	3.9(14.0)	2.0(3.0)	1.7(2.0)	6.6(42.3)	1.8(2.4)	1.9(2.6)	1.7(2.0)
Weedy check	8.1(64.9)	8.2(66.9)	8.4(69.1)	8.4(70.3)	6.6(42.4)	7.1(48.9)	8.3(67.2)	8.9(78.9)
LSD (p=0.05)	NS	0.57	0.45	0.40	NS	0.47	0.42	0.45

Figures in the parentheses are original values. Data subjected to $(\sqrt{x+1})$ square root transformation; DAA - Days after application

Table 4. Weed control efficiency (WCE), Weed control index (WCI), Weed index (WI) and Herbicide efficiency index (HEI) as influenced by different weed management options in direct-seeded rice (mean data of 2 years)

Treatment	WCE (%)			WCI (%)			WI (%)	HEI (%)
	15 DAA	30 DAA	45 DAA	15 DAA	30 DAA	45 DAA		
Pyribenzoxim 5% EC 25 g/ha	61.3	72.7	75.6	68.9	72.2	74.6	13.2	30.3
Pyribenzoxim 5% EC 30 g/ha	61.4	76.2	78.6	72.3	74.9	77.2	8.0	38.4
Pyribenzoxim 5% EC 35 g/ha	61.5	76.4	79.0	72.3	75.4	77.5	6.7	40.7
Pyribenzoxim 5% EC 60 g/ha	70.0	86.7	88.3	82.9	85.5	86.4	4.8	43.4
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	47.3	49.5	50.1	45.1	53.9	54.5	16.4	25.6
Oxadiargyl 80% WP 100 g/ha	63.6	77.6	79.9	75.3	78.4	79.3	6.0	41.6
Hand weeding	79.2	95.6	97.2	95.1	96.0	97.4	0.0	50.5
Weedy check	0.0	0.0	0.0	0.0	0.0	0.0	33.3	0.0

DAA - Days after application

Table 5. Growth and yield components and grain yield of direct-seeded rice as influenced by different weed management options (pooled data of 2 years)

Treatment	Growth component			Yield component				Grain yield (t/ha)		
	Plant height at harvest (cm)	No. of tillers/m^2 at 90 DAS	LAI at 90 DAS	No. of panicles/m^2 at harvest	Panicle length at harvest (cm)	No. of filled grains/ panicle	Test weight (g)	2017	2018	Pooled data
Pyribenzoxim 5% EC 25 g/ha	80.4	260.7	3.50	204.3	17.6	80.00	26.87	3.79	4.10	3.95
Pyribenzoxim 5% EC 30 g/ha	82.9	270.0	4.10	217.7	17.9	81.67	26.27	4.13	4.24	4.19
Pyribenzoxim 5% EC 35 g/ha	83.0	273.3	4.11	213.7	18.9	82.67	26.95	4.25	4.24	4.24
Pyribenzoxim 5% EC 60 g/ha	85.1	285.3	4.19	223.3	18.8	82.33	26.51	4.34	4.32	4.33
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	75.1	259.3	3.45	195.0	17.7	80.33	26.10	3.64	3.97	3.80
Oxadiargyl 80% WP 100 g/ha	84.5	278.0	4.16	226.0	18.3	82.00	26.23	4.42	4.13	4.27
Hand weeding	86.4	303.7	4.28	246.0	19.0	83.00	26.00	4.57	4.53	4.55
Weedy check	71.0	200.7	2.90	150.0	17.0	79.33	27.15	3.09	2.98	3.03
LSD (p=0.05)	3.3	45.0	0.45	42.5	NS	NS	NS	0.46	0.37	0.30

DAS – Days after sowing; LAI – Leaf area index

Table 6. Correlation matrix among weed density, weed dry weight, grain yield and yield components of direct-seeded rice (mean data of 2 years)

Treatment	Weed density (no./m^2)	Weed dry weight (g/m^2)	Grain yield (t/ha)	No. of panicles/m^2	Panicle length (cm)	No. of filled grains/panicle	Test weight (g)
Weed density (no./m^2)	1						
Weed dry weight (g/m^2)	.998**	1					
Grain yield (t/ha)	-.982**	-.983**	1				
No. of panicles/m^2	-.969**	-.971**	.990**	1			
Panicle length (cm)	-.822*	-.818*	.887**	.853**	1		
No. of filled grains/panicle	-.815*	-.808*	.895**	.870**	.964**	1	
Test weight (g)	.511	.549	-.456	-.496	-.199	-.160	1

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Table 7. Production economics of direct-seeded rice as influenced by different weed management options (mean data of 2 years)

Treatment	Gross returns (×10^3 ₹/ha)			Net returns (×10^3 ₹/ha)			B:C ratio		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Pyribenzoxim 5% EC 25 g/ha	61.56	70.46	66.01	32.65	41.55	37.10	2.13	2.44	2.28
Pyribenzoxim 5% EC 30 g/ha	66.82	72.45	69.63	37.76	43.39	40.57	2.30	2.49	2.40
Pyribenzoxim 5% EC 35 g/ha	68.50	72.51	70.50	39.29	43.30	41.29	2.34	2.48	2.41
Pyribenzoxim 5% EC 60 g/ha	70.39	74.49	72.44	40.43	44.53	42.48	2.35	2.49	2.42
Fenoxaprop-p-ethyl 6.7% EC 56.95 g/ha	59.52	68.39	63.95	30.30	39.17	34.73	2.04	2.34	2.19
Oxadiargyl 80% WP 100 g/ha	70.34	70.42	70.38	41.18	41.26	41.22	2.41	2.41	2.41
Hand weeding	73.87	78.09	75.98	36.21	40.43	38.32	1.96	2.07	2.02
Weedy check	50.34	51.46	50.90	22.68	23.80	23.24	1.82	1.86	1.84

respectively). This result was in agreement with the findings of Mondal *et al.* (2019).

Production economics

Gross returns were higher than cultivation costs in all the weed management options including un-weeded control. The highest net returns (₹ 42,480/ ha) and benefit-cost ratio (2.42) were obtained from pyribenzoxim 5% EC 60 g/ha spraying treatment **(Table 7)**. Hand weeding treatment provided maximum gross returns (₹ 75,980/ha) but high labour wages made it costly by reducing the net returns than herbicide applied treatments. This result was in line with the findings of Maity and Mukherjee (2009).

Based on this field study, it can be concluded that foliar application of pyribenzoxim 5% EC 60 g/ha at 15 DAS as post-emergence would be the most effective for controlling the weed flora in dry direct-seeded rice.

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