J. Indian Soc. Coastal Agric. Res. 42(2):53-60(2024) https://doi.org/10.54894/JISCAR.42.2.2024.139653

Effect of Sequential Application of Herbicides in Direct-seeded Rice under Medium Black Soils of Konkan

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Received: 24.07.2023 Accepted: 15.06.2024

A field experiment was conducted at the Agricultural Research Station, Repoli, Dist. Raigad (Maharashtra) during the *Kharif* seasons of 2019, 2020 and 2021 to study the effect of sequential application of herbicides on weed population, yield and economics of direct seeded rice (*Oryza sativa* L.). The experiment was laid out in randomized block design with three replications and seven treatments, *viz.*, Oxadiargyl 80% WP (Pre-emergence, PE) @ 100 g ha^{-1}, Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} followed by (*fb*) hand weeding (HW) at 30 DAS, Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} fb Bispyribac-Na @ 25 g ha^{-1} at 25 days after sowing (DAS), Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g ha^{-1} at 25 DAS, Oxadiargyl 80% WP (PE) @100 g ha^{-1} *fb* Carfentrozone ethyl 40% @ 25 g ha^{-1} at 25 DAS. These weed control treatments were compared with hand weeding twice at 20 and 40 DAS weed-free check, and weedy check. Application of Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} fb HW at 30 DAS recorded significantly lowest number of weeds m^2, dry weight m^2 and recorded the higher grain and straw yield (4.02 and 4.87 t ha^{-1} respectively) and B:C ratio (1.48). Among sequential herbicide treatments, application of Oxadiargyl 80% WP (PE) *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g ha^{-1} at 25 DAS recorded the least number of weeds m^2 and dry weight m^2 as compared to other sequential herbicide treatments.

(**Key words:** *Direct seeded rice, Pre- and post-emergence herbicides, Sequential application, Weed density*)

Konkan region is a narrow coastal lowland, that gets about 2072- 3800 mm annual average rainfall (Dakhore *et al.,* 2017). The major traditional agricultural crops include rice, millet and pulses among field crops. Rice is an important food crop extensively grown in Konkan, which is widely planted manually by transplanting 20 to 30-days-old seedlings into puddled soil. However, transplanting is becoming increasingly challenging due to unavailability and the high cost of labour and energy, restricted irrigation water supply and decline in soil quality (Chauhan, 2012).

Rice cultivation by direct seeding is viewed as both a cost and labor-saving practice (Kaur and Singh, 2017) and is becoming a popular alternative to transplanting. However, weeds pose serious problems in direct-seeded rice (DSR) than in transplanted rice as they compete with crops in their early growth cycle. Weeds should be controlled before they compete with rice plants or produce seeds. Minimizing weed seed production and reducing weed seed bank in the soil is critical for effective weed management (Shekhawat *et al.,* 2020; Zhang *et al.,* 2021).

Zahoor *et al.* (2014) reported that weed infestation can reduce grain yield by 90% in direct-seeded rice grain. However, it is very difficult to control the complex weed flora observed in DSR with the application of a single pre- or post-emergence herbicide (Mahajan *et al.,* 2013). Thus, effective weed management during the early stages of crop growth promises for accomplishment of higher yields. Although manual weeding is effective, it is costly, tedious and time-consuming. Due to the morphological similarity, often it is difficult to distinguish some grassy weeds from rice at early stages and sometimes deficit or excessive soil moisture may not permit efficient weeding. The scarcity of manpower at critical periods of weed infestation is an important hurdle for timely weeding in rice. Relying on herbicides may be the best choice of labour-saving technology for timely weed control. On the other side, farmers are also looking forward to the selective herbicides applied as pre- and or post-emergence to obtain cost-effective management of broad-spectrum weeds right from the

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initial stages compared to hand weeding. However, increased consciousness about the chemical pollution of soil and water has widened the scope for exploring the advantage of low-dose herbicides such as C, which are very effective against a wide range of weeds in a short time even at as low as few grams per hectare. In cognizance of the above facts, the present investigation was carried out to evaluate the effects of sequential herbicide application on yield and economics of direct-seeded *Kharif* rice in the Konkan region of Maharashtra.

MATERIALS AND METHODS

The field experiment was conducted during the *Kharif* seasons of 2019, 2020 and 2021, at Agricultural Research Station, Repoli, Dist. Raigad in the state of Maharashtra. The soil of the experimental site was medium black soil with a pH of 6.5. It was low in available nitrogen and phosphorus and high in potassium. The experiment was laid out in randomized block design with three replications and seven treatments, *viz.,* Oxadiargyl 80% WP (Pre-emergence, PE) @ 100 g ha^{-1}, Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} followed by (*fb*) hand weeding (HW) at 30 Days after sowing (DAS), Oxadiargyl 80% WP (PE)@ 100 g ha^{-1} *fb* Bispyribac-Na @ 25 g ha^{-1} at 25 DAS, Oxadiargyl 80% WP (PE) @100 g ha^{-1} *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g a.i. ha^{-1} at 25 DAS, Oxadiargyl 80% WP (PE) @100 g ha^{-1} *fb* Carfentrozone ethyl 40% @ 25 g ha^{-1} at 25 DAS. These weed control treatments were compared with hand weeding twice at 20 and 40 DAS weed-free check, and weedy check.

Karjat-5 variety of rice was sown at a row spacing of 20 cm. It is a mid-late (125-130 days) duration variety maturing in 125 to 130 days and having a yield potential of 5.0-5.5 t ha^{-1}. The variety is semi-dwarf in stature, having long bold grains, resistant to neck blast, and suitable for midland under both rainfed and irrigated conditions. The crop was fertilized with 100:50:50 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Half the dose of N and full doses of P_2O_5 and K_2O were applied at sowing and the remaining dose of N was applied in two splits. Herbicides were applied with a manually operated knapsack sprayer with a flat fan nozzle. In hand weeding, weeds were removed manually. Data on weed density and dry weight of weed were recorded after 60 days of sowing in each plot in four quadrats each of 25 x 25 cm. Weeds were counted in three categories *i.e.,* grasses, broad leaf weeds and sedges, and were removed for recording the dry weight of weeds. Weed samples were sun-dried before oven drying at 70°C until a constant weight was attained. Yield and yield attributes of rice were recorded at crop harvest. Weed control efficiency was also calculated based on dry matter production of weeds (Mani *et al.,* 1976).

$$\text{Weed control efficiency (WCE)} = \frac{(WD_c - WD_t)}{WD_c} \times 100 \quad ...(1)$$

where, WD_c is the biomass of weeds in weedy plots, WD_t is the biomass of weeds in treated plots

Data on weeds were subjected to square-root transformation ($\sqrt{x}$+0.5) before statistical analysis (Mani *et al.,* 1976). All the data were analyzed by using ANOVA, and the least significant values at a 5% level of significance were calculated and used to test significant difference treatment means.

RESULTS AND DISCUSSION

Effect on weed flora

On average, a weed population of 279 m^{-2} was recorded in the weedy check plot. The major grassy weeds observed in the direct-seeded rice experimental plot were *Echinochloa colona, Echinocloa crusgalli* and *Ischane globose* while, *Cyperus iria* and *Cyperus diformis* were the dominant weeds among sedges and *Eclipta alba* (L.), *Commellina difusa* were prominent among broad-leaved weeds (BLWs). Weed density under weedy check showed that monocot weeds (grasses and sedges) were more predominant that is grasses constituted 74.80%, BLWs 14.20% and particularly sedges constituted 11.48% of the total weed density at 60 DAS of the crop. These findings conform with the findings of Mondal *et al.* (2019) who observed monocot weeds particularly sedges being the dominant weed species in direct-seeded rice.

Effect on weed density

Data on the weed density at 20, 40 and 60 DAS and harvest are presented in Table 1. It was observed that all the weed-control treatments significantly reduced the weed density compared to weedy check. The highest weed density was recorded in the weedy check is attributable to uncontrolled weed growth. Weed-free check recorded significantly lower total weed density at 20, 40 and 60 DAS and harvest stages of crop. In the case of herbicide treatments, application of Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* HW at 30 DAS (T_2) treatment resulted in significantly lower weed density of grassy, sedges and broadleaf weeds at 40, 60 DAS and harvest compared other treatments. However, among sequential herbicide treatments, application of Oxadiargyl 80% WP (PE) *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g ha^{-1} at 25 DAS (T_4) registered the significantly lower density of grassy, sedges and broadleaf weeds at 40, 60 DAS and at harvest as compared to other sequential herbicide treatments.

Dry biomass is the way of expressing weed dominance in the plot. Biomass provides information about the accumulation of growth. The dry biomass of grasses, broadleaf and sedges was lower with the application of Oxadiargyl 80% WP (PE) @100 g ha^{-1} *fb* HW at 30 DAS (T_2) treatment compared with the weedy check at 40, 60 DAS and at harvest stages of the crop (Table 2). A sequential herbicide treatment, application of Oxadiargyl 80% WP (PE) *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g ha^{-1} at 25 DAS (T_4) registered the significantly lower density of grassy, sedges and broadleaf weeds at 40, 60 and at harvest stages of the crop as compared to other sequential herbicide treatments. This might be due to retardation of weed growth after herbicide application. The weeds exhibited stunting, interveinal chlorosis and gradual death that decreased weed density and dry weight of weeds resulting in good growth of crop. Singh *et al.* (2016) reported the initial effectiveness of pre-emergence herbicides such as pendimethalin and oxadiargyl alone but their performance declined at 45 DAS. Singh *et al.* (2005) emphasized the importance of the sequential application of pendimethalin as pre-emergence and chlorimuron + metsulfuron as post-emergence in realizing reduced grass population. These results conform with the findings of Rajkhowa *et al.* (2005), Hemalatha *et al.* (2017) and Yogananda *et al.* (2017).

Effect of different herbicide on weed control efficiency

The highest weed control efficiency was observed in weed-free check treatment (T_6) during all the stages and pooled analysis. Among herbicidal treatments, T_2 (Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* HW at 30 DAS) recorded the maximum weed control efficiency. Among sequential herbicide treatments, application of Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g ha^{-1} at 25 DAS (T_4) recorded the highest weed control efficiency (Table 3). The highest weed control efficiency might be attributed to successive application of two herbicides at an interval of 20 days resulting in a reduction in total weed biomass which was comparable with weed-free check. Hemlatha *et al.* (2017) reported that pre-emergence application of Pendimethalin *fb* post-emergence application of Metasulfuron-methyl + Chlorimuron-ethyl registered the highest weed control efficiency (89.7%) which was comparable with the weed-free check (90.6%). These results of the present study are also in agreement with the findings of Walia *et al.* (2012), Dahiphale *et al.* (2015) and Mahadkar *et al.* (2015).

Effect of different herbicides on crop yield

From the data presented in Table 3, it is evident that all weed control treatments showed significantly higher values of grain and straw yield of rice compared to un-weeded control mainly due to effective suppression of weeds that resulted in improved uptake of inputs like nutrients, light, moisture and other resources by crop. Weed-free check treatment (T_6) recorded significantly higher grain (4.32 t ha^{-1}) and straw yield (5.19 t ha^{-1}) of rice than the rest of the weed-control treatments owing to better control of weeds. Among herbicidal and sequential herbicidal treatments, significantly higher grain yield (4.02 t ha^{-1}) and straw yield (4.88 t ha^{-1}) was recorded with application of Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* HW at 30 DAS (T_2) as compared with other treatment whereas it was at par with Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g a.i. ha^{-1} at 25 DAS (T_2) was applied. Significantly lower grain yield and straw yield were recorded with the weedy check (2.05 and 2.45 t ha^{-1}, respectively). The enhanced yields under these treatments were because of the elimination of weeds which helped in enhancing the availability of nutrients, space, sunlight and water resulting in better growth and development of crop plants. Similarly, among the herbicide treatments, a lower weed index (6.98) was recorded in treatment T_2 where Oxadiargyl 80% WP

Table 1. *Effect of different herbicides on weed density in direct-seeded rice (Pooled data of 3 years)*

Treatments	No. of weeds m^{-2}												Total no. of weeds m^{-2}			
					Broad leaf weeds				Sedges							
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
T_1: Oxadiargyl 80% WP (PE) @ 100 g ha^{-1}	5.28 (27.56)	5.86 (34.00)	6.86 (46.67)	10.51 (110.0)	3.18 (9.78)	3.59 (12.45)	4.26 (17.78)	5.44 (29.33)	3.29 (10.67)	3.68 (13.33)	4.05 (16.00)	4.56 (20.45)	6.96 (48.0)	7.57 (59.77)	8.99 (80.45)	12.66 (159.78)
T_2: Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* HW at 30 DAS	5.28 (27.56)	0.71 (0.00)	2.65 (6.67)	7.84 (61.33)	3.16 (9.78)	0.71 (0.00)	2.30 (4.89)	3.63 (12.89)	3.25 (10.22)	0.71 (0.00)	2.12 (4.00)	3.47 (11.56)	6.92 (47.56)	0.71 (0.00)	4.01 (15.56)	9.27 (85.78)
T_3: Oxadiargyl 80% WP (PE) *fb* Bispyribac-Na @ 25 g ha^{-1} at 25 DAS	5.14 (26.22)	4.75 (22.22)	4.93 (24.00)	8.41 (70.67)	3.16 (9.78)	2.97 (8.45)	3.51 (12.00)	4.60 (20.89)	3.16 (9.78)	3.06 (8.89)	3.33 (10.67)	3.89 (14.67)	6.76 (45.77)	6.31 (39.56)	6.85 (46.66)	10.32 (106.22)
T_4: Oxadiargyl 80% WP (PE) *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g ha^{-1} at 25 DAS	5.01 (24.89)	4.44 (19.55)	4.53 (20.44)	7.38 (54.22)	3.12 (9.33)	2.72 (7.11)	3.03 (8.89)	4.19 (17.33)	3.16 (9.78)	2.72 (7.11)	2.90 (8.00)	3.26 (10.22)	6.65 (44.00)	5.82 (33.77)	6.12 (37.33)	9.06 (81.78)
T_5: Oxadiargyl 80% WP (PE) *fb* Carfentrozone ethyl 40% @ 25 g ha^{-1} at 25 DAS	5.20 (26.67)	4.69 (21.78)	4.90 (24.00)	8.29 (68.69)	3.23 (10.22)	2.88 (8.00)	3.38 (11.11)	4.50 (20.00)	3.14 (9.78)	3.04 (8.89)	3.32 (10.67)	3.64 (12.89)	6.84 (46.67)	6.22 (38.67)	6.75 (45.78)	10.08 (101.78)
T_6: Weed-free check (2 HW at 20 & 40 DAS)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	3.92 (15.56)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	2.56 (6.22)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	2.30 (4.89)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	5.15 (26.67)
T_7: Unweeded check (control)	9.70 (94.22)	10.44 (108.89)	11.32 (127.78)	14.43 (208.44)	4.85 (23.11)	5.50 (29.78)	5.93 (34.67)	6.32 (39.56)	4.41 (19.11)	4.98 (24.44)	5.41 (28.89)	5.58 (30.67)	11.69 (136.44)	12.79 (163.11)	13.85 (191.33)	16.70 (278.67)
SEm±	0.25	0.22	0.27	0.33	0.13	2.09	0.12	0.19	0.16	0.14	0.12	0.10	0.27	0.24	0.26	0.29
C.D. at 5 %	0.77	0.67	0.83	1.02	0.41	6.44	0.38	0.57	0.48	0.42	0.37	0.31	0.83	0.74	0.80	0.91

(Figures in parentheses are original values, which were subjected to square root transformation ($\sqrt{x} + 0.5$) before statistical analysis)
PE - Pre-emergence; HW - Hand weeding; *fb* - Followed by

Table 2. *Effect of different herbicides on dry weight of weeds in direct-seeded rice cultivation system (Pooled data of 3 years)*

Treatments	Dry weight. of weeds (g m^{-2})												Total dry weight. of weeds (g m^{-2})			
	Grasses				BLW				Sedges							
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
T_1: Oxadiargyl 80% WP (PE) @ 100 g ha^{-1}	1.75 (1.83)	2.09 (3.90)	2.73 (7.00)	4.66 (21.23)	1.19 (0.69)	1.39 (1.45)	1.97 (3.40)	2.66 (6.58)	1.13 (0.53)	1.41 (1.49)	1.63 (2.17)	2.03 (3.67)	1.88 (3.05)	2.71 (6.84)	3.61 (12.57)	5.65 (31.47)
T_2: Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* HW at 30 DAS	1.75 (1.91)	0.71 (0.00)	1.22 (1.00)	3.50 (11.83)	1.19 (0.65)	0.71 (0.00)	1.19 (0.93)	1.84 (2.92)	1.12 (0.65)	0.71 (0.00)	1.02 (0.54)	1.60 (2.07)	1.92 (3.21)	0.71 (0.00)	1.72 (2.47)	4.15 (16.81)
T_3: Oxadiargyl 80% WP (PE) *fb* Bispyribac-Na @ 25 g ha^{-1} at 25 DAS	1.71 (1.91)	1.74 (2.55)	2.01 (3.59)	3.75 (13.65)	1.19 (0.65)	1.21 (0.99)	1.66 (2.29)	2.28 (4.71)	1.10 (0.61)	1.22 (1.00)	1.39 (1.45)	1.76 (2.62)	1.91 (3.17)	2.24 (4.54)	2.79 (7.33)	4.63 (20.98)
T_4: Oxadiargyl 80% WP (PE) *fb* Metasulfuron-ethyl + chlorimuron-ethyl @ 4 g ha^{-1} at 25 DAS	1.68 (2.00)	1.64 (2.25)	1.87 (3.05)	3.31 (10.47)	1.18 (0.78)	1.15 (0.82)	1.47 (1.70)	2.09 (3.89)	1.10 (0.65)	1.13 (0.80)	1.25 (1.08)	1.52 (1.83)	1.98 (3.43)	2.08 (3.87)	2.50 (5.83)	4.08 (16.19)
T_5: Oxadiargyl 80% WP (PE) *fb* Carfentrozone ethyl 40% @ 25 g ha^{-1} at 25 DAS	1.73 (1.79)	1.72 (2.51)	2.01 (3.58)	3.70 (13.31)	1.21 (0.65)	1.19 (0.93)	1.61 (2.13)	2.23 (4.47)	1.10 (0.53)	1.22 (0.99)	1.39 (1.46)	1.67 (2.33)	1.86 (2.97)	2.21 (4.43)	2.75 (7.17)	4.53 (20.11)
T_6: Weed-free check (2 HW at 20 & 40 DAS)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	1.84 (3.01)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	1.36 (1.38)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	1.16 (0.86)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	2.38 (5.25)
T_7: Unweeded check (control)	3.03 (3.59)	3.52 (11.91)	4.43 (19.11)	6.37 (40.27)	1.65 (1.47)	1.98 (3.44)	2.67 (6.65)	3.08 (9.06)	1.38 (1.26)	1.76 (2.61)	2.10 (3.94)	2.43 (5.47)	2.61 (6.32)	4.30 (17.96)	5.49 (29.70)	7.43 (54.81)
SEm±	0.07	0.06	0.10	0.14	0.03	0.03	0.05	0.09	0.03	0.03	0.05	0.05	0.05	0.06	0.10	0.12
C.D. at 5 %	0.20	0.19	0.31	0.44	0.10	0.10	0.16	0.28	0.09	0.09	0.15	0.16	0.17	0.19	0.31	0.38

(Figures in parentheses are original values, which were subjected to square root transformation ($\sqrt{x} + 0.5$) before statistical analysis)
PE - Pre-emergence; HW - Hand weeding; *fb* - Followed by

Table 3. *Effect of different herbicides on weed control efficiency (%), yield and economics of direct-seeded rice (Pooled data of 3 years)*

Treatments	Weed control efficiency (%)				Yield and economics of rice				
	20 DAS	40 DAS	60 DAS	At harvest	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Weed index	Net return over input cost (₹)	Benefit-cost ratio on input cost
T_1: Oxadiargyl 80 % WP (PE) @ 100 g ha^{-1}	65.10	57.59	57.68	42.58	2.84	3.40	34.25	9518	1.17
T_2: Oxadiargyl 80 % WP (PE) @ 100 g ha^{-1} *fb* HW at 30 DAS	65.30	100.0	91.70	69.30	4.02	4.88	6.98	29974	1.48
T_3: Oxadiargyl 80 % WP (PE) *fb* Bispyrib-ac-Na @ 25 g ha^{-1} at 25 DAS	66.56	70.58	75.32	61.72	3.56	4.22	17.74	22403	1.38
T_4: Oxadiargyl 80 % WP (PE) *fb* Metasul-furon-ethyl + chlo-rimuron-ethyl @ 4 g ha^{-1} at 25 DAS	67.85	72.97	80.37	70.46	4.02	4.82	7.03	29826	1.48
T_5: Oxadiargyl 80 % WP (PE) *fb* Carfen-trozone ethyl 40% @ 25 g ha^{-1} at 25 DAS	65.99	68.95	75.86	63.31	3.66	4.35	15.43	25670	1.44
T_6: Weed-free check (2HW at 20 & 40 DAS)	100.0	100.0	100.0	90.4	4.32	5.19	0.00	34215	1.52
T_7: Unweeded check (control)	0	0	0	0	2.05	2.45	52.66	-2250	0.72
SEm±	-	-	-	-	0.067	0.088	-	-	-
C.D. at 5 %	-	-	-	-	0.205	0.269	-	-	-

(PE - Pre-emergence; HW - Hand weeding; *fb* - Followed by

(PE) @ 100 g ha^{-1} was applied *fb* HW at 30 DAS (T_2) followed by treatment T_4 (weed index 7.03) in which Oxadiargyl 80 % WP (PE) @ 100 g ha^{-1} *fb* Metasulfuron-methyl + chlorimuron-ethyl @ 4 g ha^{-1} at 25 DAS was applied. Pinjari *et al.* (2016) observed that different weed control treatments significantly influenced the yield attributes, *viz.,* plant height, number of tillers and weight of filled grains per panicle over the weedy check. Similar results were reported by Rajkhowa *et al.* (2005), Walia *et al.* (2012) and Linganagouda *et al.* (2019).

Economics of the different treatments

The data regarding the economics of different weed control treatments are presented in Table 3. The weed-free check recorded higher net profit on input cost (INR 34215) and B:C ratio (1.52) than other remaining treatments. Among herbicide treatments, T_2 recorded a net profit of INR 29974 and a B:C ratio of 1.48; treatment T_4 recorded a net profit of INR 29,826 and a B:C ratio of 1.48. The lower net returns were recorded in the weedy check (INR 2,250) compared to all other treatments. Similar results of higher net returns and B:C ratio in direct-seeded rice due to sequential application of herbicides were also reported by Pinjari *et al.* (2016). Yogananda *et al.* (2017) observed that the highest net returns and B:C ratio were recorded with pre-emergence application of Bensulfuron-methyl + Pretilachlor @ 660 g ha^{-1} *fb* post-emergence application of Bispiribac-sodium @ 25 g ha^{-1}. The increase in benefits can be attributed mainly to higher grain yield and reduced labour costs.

CONCLUSION

Based on three years pooled data it is concluded that application of sequential herbicide Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* Metasulfuron-methyl + Chlorimuron-ethyl @ 4 g a.i. ha^{-1} at 25 DAS or Oxadiargyl 80% WP (PE) @ 100 g ha^{-1} *fb* HW at 30 DAS can effectively control the weeds for realizing higher yields and economic benefits in direct-seeded rice during *Kharif* season.

CONFLICTS OF INTEREST

The authors have no conflicts of interest.

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