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RESEARCH ARTICLE

Sequential application of herbicides for weed management in direct-seeded basmati rice

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ABSTRACT

Due to the water issue and labour shortage during cultivation of rice in India, there is an urgent need to shift towards the alternatives of puddled transplanted rice. Therefore, direct-seeded rice (DSR) is emerging as a productive technique in place of puddle transplanted rice to tackle this situation. The primary biological obstacles to its success, however, are weeds. Therefore, a study has been conducted comprising of 10 treatments with three replications in direct-seeded rice cv. '*Basmati 370'* during the *Kharif* (rainy) seasons of 2018 and 2019 at Research Farm of AICRP-Weed Management, Chatha, SKUAST-Jammu in a randomized block design. At 60 DAS, significantly lowest density as well as biomass of grassy weeds were recorded in oxyfluorfen 175 g/ha as pre-emergence (PE) *fb* fenoxaprop-p-ethyl + 2,4-D-EE (60+500 g/ha) at 25 days after sowing (DAS). However, significantly lowest *Cyperus* species density and biomass was noticed in pendimethalin 1000 g/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 days after sowing. More than 80% weed control efficiency was observed in oxyfluorfen 175 g/ha as pre-emergence (PE) *fb* fenoxaprop-p-ethyl + 2,4-D-EE (60+500 g/ha), pendimethalin 1000 g/ha as PE *fb* bispyribac-sodium 25 g/ha and pretilachlor 600 g/ha *fb* penoxsulam + cyhalofop-butyl 150 g/ha. In addition to this, the results revealed that significantly higher grain and straw yield of rice with highest net returns and benefit cost ratio were observed in pendimethalin 1000 g/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS. The findings of this study will help farmers who are cultivating direct-seeded rice to make decisions on the application of herbicides based on the weed flora existing in the field.

Keywords: Basmati rice**,** Direct-seeded rice, Herbicide, Weed control efficiency, Weed management

INTRODUCTION

With 25% of the world's rice production, India is the one of the top producers in the world. With a projected rise in output, India is expected to produce more than 130 million metric tonnes of rice in the year 2023. Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Delhi, Uttarakhand, and Western Uttar Pradesh are the Indian states famous for Basmati rice (NCML 2019). To meet the global rice demand, it is estimated that about 114 million tons of additional milled rice need to be produced by 2035, which is equivalent to an overall increase of 26% in the next 25 years (Kumar and Ladha 2011).

Three main techniques are used to grow rice, *viz*. transplanting, dry-seeding and wet-seeding. Traditional transplanted rice is now quickly being replaced by direct-seeding in locations with good drainage and irrigation systems (Balasubramanian and Hill 2000). Direct-seeded rice (DSR) has a lot of advantages, but it also needs careful management. Direct-seeded rice plants are more vulnerable to weed competition in the early phases of growth where weed control is more difficult. Also, dry tillage and aerobic soil conditions favours the germination and growth of weeds, which can result in losses of 50 to 90 per cent in grain output (Chauhan and Johnson 2011, Chauhan and Open 2012, Chauhan *et al.* 2011, Prasad 2011). Because there are fewer weed control alternatives in DSR than in transplanted rice, research has revealed that grain yield losses are larger in DSR than on transplanted rice (Baltazar and De Datta 1992, Chauhan and Johnson 2010). The presence of standing water that limits light to weed seeds buried in the soil and the absence of weed seedlings are the two reasons giving transplanted rice a upper hand over the DSR (Baltazar and De Datta 1992, Chauhan 2012 and Chauhan and Johnson 2010). Hence, adequate weed management is crucial for successful DSR production. Herbicides, mechanical cultivation and cultural techniques can all be used in conjunction to manage weeds and reduce weed competition to maintain a healthy and successful rice crop. It is crucial to properly evaluate the individual weed stress in each field and select the best weed control strategies for that environment. The availability of systematic herbicide is crucial to change weed

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composition environment in DSR systems. To give farmers more options for weed management in DSR, it is vital to assess various pre and post herbicides. Therefore, the present investigation was carried out with the objective to study the effect of pre- and post-emergence herbicidal weed management on weed flora dynamics and productivity of basmati rice.

MATERIALS AND METHODS

The present field experiment was conducted during the *Kharif* (rainy season of 2018 and 2019 at Research Farm of AICRP-Weed Management, Chatha, SKUAST-Jammu in a randomized block design with three replications having ten treatments namely pendimethalin1000 g/ha as PE, pretilachlor 600 g/ha as PE, oxyfluorfen 175 g/ha as PE, bispyribac-sodium 25 g/ha at 25 DAS, penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS, fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS, pendimethalin1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS, pretilachlor 600 g/ha *fb* penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS, oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS and control (weed check).

The experimental site was situated at 32.6529° N latitude and 74.8071° E longitude at an elevation of 332 meters above mean sea level. The average annual rainfall in the experimental area was 1115 mm, of which 70-75% is from June to September, and the remaining 25-30% though small number of showers from the western disturbances in January to March in winter. The region has a subtropical climate with hot, dry summers followed by a hot and humid monsoon season. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen but medium in phosphorus and potassium. The rice variety '*Basmati 370*' was sown on 16th June 2018 and 15th June 2019 and harvested on 28th October 2018 and 5th November 2019, respectively. The gross plot size was 6.0 x 4.4 m. In direct-seeded rice, pre-emergence herbicide pendimethalin 1.0 kg/ha, pretilachlor 600 g/ha and oxyfluorfen 175 g/ha were applied on same day of sowing and all the post-emergence herbicides were applied at 25 days after sowing using 500 L water/ha. All the herbicides were applied by using a Knapsack sprayer fitted with flat fan nozzle. The recommended doses of 30 kg N + 20 kg P + 10 kg K/ha were uniformly applied. Full dose of P and K, and half N were applied as basal at the time of sowing, whereas rest of the N was given in two equal splits as top dressing at mid tillering stage and panicle initiation stage. Besides the rainfall, field was kept under moist conditions by applying irrigation as and when hair line cracks appeared throughout the crop growth. Data on weed density and biomass of weeds were recorded at 30 days after sowing and 60 days after sowing of crop using 1 x 1 m quadrate and was subjected to square root transformation by adding 1.0 to original values prior to statistical analysis. Data on yield and yield attributes were recorded at the time of crop harvest.

RESULTS AND DISCUSSION

Effect of different weed management treatments on weeds

The experimental field was dominated by *Echinochloa* spp. and *Digitaria sanguinalis* amongst grassy weeds; *caesulia axillaris* and *Physalis minima* amongst broad-leaved weeds and *Cyperus* spp. *(difformis* and *iria)*. Beside these major weeds, *Commelina benghalensis, Cucumis* spp., *Euphorbia* spp. and *Dactyloctenium aegyptium* were recorded as other weeds.

Different pre-emergence herbicides treatments showed significant effect on total weed density at 30 DAS in direct-seeded rice (**Table 1**). Among pre-emergence herbicides, oxyfluorfen 175 g/ha recorded significantly lowest total weed density as compared to pendimethalin 1000 g/ha and pretilachlor 600 g/ha during both the years. At 60 DAS, different weed management treatments had significant effect on the grassy weeds, broad-leaved weeds, *Cyperus* spp. *(difformis* and *iria)* and another weed. Under the grassy weeds, results revealed that oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS exhibited lowest density of *Echinochloa* spp. which was noticed to be statistically at par with pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS and significantly lower than other treatments. Similarly, oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS resulting in the significantly lowest weed density of *Digitaria sanguinalis* than other treatments (**Table 2**). It was also observed that fenoxaprop-p-ethyl applied treatments exhibited higher control of *Digitaria sanguinalis* than other herbicides. Blouin *et al.* (2010) also reported that fenoxaprop-p-ethyl provides excellent control of major grasses such as *L. chinensis*, *D. aegyptium, D. sanguinalis* and *E. colona* that are predominant in DSR.

In the case of broad-leaved weeds, oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS exhibited the lowest weed density for both *C. axillaris* and *P. minima* which was statistically at par with pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS in case of *C. axillaris*. Similar trend was observed in case of other weed species that oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS exhibiting the lowest weed density than other treatments.

For the *Cyperus* species *(difformis* and *iria)*, the lowest weed density was noticed to be under the pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ ha at 25 DAS herbicidal treatment which was found to be statistically at par with pretilachlor 600 g/ha *fb* penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS during both the years and significantly lower than other treatments. Similarly, the lowest total weed density was noticed with pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS which was statistically at par with oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS herbicidal treatment. Similar results were reported by Walia *et al.* (2008) where bispyribac-sodium effectively controlled all common predominant weeds, including all *Cyperus* spp. and *Echinochloa* spp. The lowest total weed biomass was noticed with oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS which was statistically at par with pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS herbicidal treatment (**Table 3**). The sequential application of pre- and post-emergent herbicides showed significantly better weed control efficiency than alone

Table 1. Effect of weed management treatments on weed density (no./m^2) at 30 DAS in direct-seeded basmati rice (*Kharif* 2018 and 2019)

Treatment	Total weed density (no./m^2) 2018	Total weed density (no./m^2) 2019
Pendimethalin1000 g/ha as PE	7.23 (51.33)	6.90 (46.67)
Pretilachlor 600 g/ha as PE	8.06 (64.00)	7.70 (58.33)
Oxyfluorfen 175 g/ha as PE	6.16 (37.00)	6.11 (36.33)
Bispyribac-sodium 25 g/ha at 25 DAS	10.72 (114.00)	10.41 (107.33)
Penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS	10.80 (115.67)	10.34 (106.00)
Fenoxaprop-p-ethyl + 2-4-D -EE (60+500 g/ha) at 25 DAS	10.74 (114.33)	10.42 (107.67)
Pendimethalin1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS	7.18 (50.67)	6.83 (45.67)
Pretilachlor 600 g/ha *fb* penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS	8.10 (64.67)	7.79 (59.67)
Oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2-4-D -EE (60+500 g/ha) at 25 DAS	6.38 (39.67)	6.22 (37.67)
Control	10.89 (117.67)	10.38 (106.67)
LSD (p=0.05)	0.38	0.41

Data was subjected to square root transformation ($\sqrt{x+1}$). Original values are in parentheses

Table 2. Effect of weed management treatments on weed density (no./m^2) at 60 DAS in direct-seeded basmati rice

Treatment	Grassy weeds				Broad-leaved weeds				*Cyperus* spp.		Other		Total	
	Echinochloa sp.		*D. sanguinalis*		*C. axillaris*		*P. minima*							
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Pendimethalin1000 g/ha as PE	3.55 (11.67)	3.61 (12.00)	2.44 (5.00)	2.31 (4.33)	2.24 (4.00)	2.31 (4.33)	2.51 (5.33)	2.45 (5.00)	5.83 (33.00)	5.74 (32.00)	3.05 (8.33)	2.89 (7.33)	8.26 (67.33)	8.12 (65.00)
Pretilachlor 600 g/ha as PE	4.04 (15.33)	4.12 (16.00)	2.77 (6.67)	2.58 (5.67)	2.58 (5.67)	2.45 (5.00)	2.71 (6.33)	2.45 (5.00)	6.38 (39.67)	6.24 (38.00)	3.27 (9.67)	3.06 (8.33)	9.18 (83.33)	8.89 (78.00)
Oxyfluorfen 175 g/ha as PE	3.27 (9.67)	3.06 (8.33)	2.16 (3.67)	2.31 (4.33)	1.82 (2.33)	2.00 (3.00)	2.00 (3.00)	2.08 (3.33)	5.42 (28.33)	5.26 (26.67)	2.58 (5.67)	2.38 (4.67)	7.33 (52.67)	7.16 (50.33)
Bispyribac-sodium 25 g/ha at 25 DAS	3.00 (8.00)	2.83 (7.00)	2.82 (7.00)	2.38 (4.67)	1.91 (2.67)	2.00 (3.00)	1.63 (1.67)	1.73 (2.00)	4.10 (16.00)	3.74 (13.00)	2.89 (7.33)	2.71 (6.33)	6.60 (42.67)	6.08 (36.00)
Penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS	3.96 (14.67)	3.42 (10.67)	2.16 (3.67)	1.83 (2.33)	1.73 (2.00)	1.91 (2.67)	1.73 (2.00)	1.73 (2.00)	4.03 (15.33)	3.79 (13.33)	2.82 (7.00)	2.65 (6.00)	6.76 (44.67)	6.16 (37.00)
Fenoxaprop-p-ethyl + 2-4-D -EE (60+500 g/ha) at 25 DAS	2.82 (7.00)	2.65 (6.00)	1.73 (2.00)	1.63 (1.67)	1.91 (2.67)	2.08 (3.33)	1.52 (1.33)	1.73 (2.00)	5.15 (25.67)	4.97 (23.67)	2.38 (4.67)	2.16 (3.67)	6.65 (43.33)	6.43 (40.33)
Pendimethalin1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS	1.63 (1.67)	1.53 (1.33)	2.00 (3.00)	1.73 (2.00)	1.52 (1.33)	1.63 (1.67)	1.41 (1.00)	1.53 (1.33)	2.82 (7.00)	2.65 (6.00)	1.91 (2.67)	1.73 (2.00)	4.20 (16.67)	3.92 (14.33)
Pretilachlor 600 g/ha *fb* penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS	1.99 (3.00)	1.83 (2.33)	2.16 (3.67)	1.83 (2.33)	1.73 (2.00)	1.83 (2.33)	1.82 (2.33)	1.63 (1.67)	3.21 (9.33)	2.94 (7.67)	2.23 (4.00)	2.00 (3.00)	5.03 (24.33)	4.51 (19.33)
Oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2-4-D -EE (60+500 g/ha) at 25 DAS	1.41 (1.00)	1.41 (1.00)	1.41 (1.00)	1.53 (1.33)	1.52 (1.33)	1.53 (1.33)	1.00 (0.00)	1.15 (0.33)	3.78 (13.33)	3.37 (10.33)	1.52 (1.33)	1.63 (1.67)	4.35 (18.00)	4.12 (16.00)
Control	5.44 (28.7)	5.69 (31.3)	3.83 (13.7)	4.00 (15.0)	2.99 (8.0)	3.11 (8.67)	3.31 (10.0)	3.74 (13.0)	7.96 (62.3)	8.27 (67.3)	3.21 (9.3)	3.51 (11.33)	11.53 (132.0)	12.15 (146.7)
LSD (p=0.05)	0.30	0.28	0.23	0.24	0.27	0.25	0.18	0.22	0.46	0.44	0.25	0.33	0.40	0.35

Data was subjected to square root transformation ($\sqrt{x+1}$). Original values are in parentheses application of either pre-emergence or post-emergence herbicides. The use of herbicide combinations, whether applied simultaneously tank-mixed or sequentially, improved weed control as compared to a single herbicide application (Mahajan and Timsina 2011and Mahajan *et al.* 2013).

Effect of different weed management treatments on yield

Among the weed management practices, all the weed management treatments recorded significantly higher grain and straw yield of rice compared to weedy check (**Table 4**). Pendimethalin 1000 g/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS resulted in highest grain yield (2.67 t/ha for 2018 and 2.57 t/ha for 2019) and straw yield (5.52 t/ha for 2018 and 5.48 t/ha for 2019) which was also found to be statistically at par with pretilachlor 600 g/ha as PE *fb* penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS for both grain yield (2.45 t/ha for 2018 and 2.39 t/ha for 2019) and straw yield (4.91 t/ha for 2018 and 4.86 t/ha for 2019). The increased availability of nutrients, water, light, and space for crop in these treatments due to successful weed control may be the cause of the improved crop development. According to Walia *et al.* (2008), pendimethalin 0.75 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha as post-emergence caused enhanced weed control to result in a 372% increase in rice grain yield in comparison to weedy check. They also observed that controlling of weeds in DSR is challenging by using single herbicide. Walia *et al.* (2012) reported that pendimethalin 0.75 kg/ha applied as pre-emergence combined with bispyribac-sodium 25 g/ha or azimsulfuron 20 g/ha as post-emergence resulted in yields that were 61.7 and 42.1% greater than pendimethalin 0.75 kg/ha applied alone. Similar results were reported by Walia *et al.* (2012) who demonstrated an increase in grain and straw yield with pre-emergence application of pendimethalin 0.75 kg/ha followed by bispyribac-sodium 25 g/ha. The oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS resulted about 90% weed control efficiency but grain and straw yields were significantly lower than pretilachlor 600 g/ha as PE *fb* penoxsulam + cyhalofop-butyl 150 g/ha and pendimethalin 1000 g/ha as PE *fb* bispyribac-sodium 25 g/ha. This was due to phytotoxicity in germination of rice caused by per-emergence application of oxyfluorfen 175 g/ha.

Effect of different weed management treatments on economics

The cost of cultivation differed for different herbicidal treatments with oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2,4-D -EE (60+500 g/ha) at 25 DAS resulting in the highest cost of cultivation (₹ 30284/ha for 2018 and ₹ 31584/ha for 2019). Pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS resulted in numerically higher gross returns (₹ 111874/ha for 2018 and ₹ 107909/ha for 2019), net return (₹ 82267/ha for 2018 and ₹ 77002/ha for 2019), and benefit cost ratio (2.78 for 2018 and 3.49 for 2019) followed by pretilachlor 600 g/ha

Table 3. Effect of weed management treatments on weed biomass (g/m^2) in basmati rice

Treatment	Weed biomass (g/m^2) at 60 DAT								WCE	
	Grassy		BLWs		Sedges		Total			
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Pendimethalin1000 g/ha as PE	4.89 (22.96)	4.84 (22.44)	3.76 (13.16)	3.62 (12.14)	4.35 (17.93)	4.22 (16.85)	7.42 (54.05)	7.24 (51.43)	52.98	57.01
Pretilachlor 600 g/ha as PE	5.51 (29.35)	5.41 (28.29)	4.26 (17.21)	4.14 (16.11)	4.68 (20.99)	4.63 (20.39)	8.27 (67.54)	8.11 (64.79)	41.24	45.84
Oxyfluorfen 175 g/ha as PE	4.36 (18.02)	4.25 (17.05)	2.97 (7.84)	2.87 (7.22)	3.99 (14.94)	3.88 (14.07)	6.46 (40.80)	6.27 (38.34)	64.51	67.94
Bispyribac-sodium 25 g/ha at 25 DAS	4.20 (16.65)	4.12 (16.01)	2.69 (6.27)	2.65 (6.03)	3.01 (8.18)	2.98 (7.89)	5.66 (31.10)	5.56 (29.92)	72.94	74.98
Penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS	4.81 (22.15)	4.69 (21.01)	2.55 (5.49)	2.47 (5.08)	3.04 (8.25)	2.96 (7.77)	6.07 (35.89)	5.91 (33.87)	68.78	71.68
Fenoxaprop-p-ethyl + 2-4-D -EE (60+500 g/ha) at 25 DAS	3.47 (11.09)	3.41 (10.65)	2.59 (5.78)	2.52 (5.34)	3.66 (12.43)	3.55 (11.58)	5.50 (29.30)	5.35 (27.57)	74.51	76.95
Pendimethalin1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS	2.61 (5.82)	2.65 (6.01)	2.02 (3.12)	1.94 (2.75)	2.16 (3.71)	2.15 (3.63)	3.69 (12.65)	3.66 (12.40)	89.00	89.64
Pretilachlor 600 g/ha *fb* penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS	3.07 (8.47)	3.04 (8.25)	2.64 (5.98)	2.39 (4.72)	2.45 (5.00)	2.40 (4.76)	4.51 (19.45)	4.33 (17.72)	83.08	85.18
Oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2-4-D -EE (60+500 g/ha) at 25 DAS	1.90 (2.61)	1.86 (2.46)	1.74 (2.07)	1.74 (2.02)	2.81 (6.92)	2.79 (6.76)	3.55 (11.61)	3.50 (11.24)	89.90	90.60
Control	7.67 (57.94)	7.79 (59.65)	5.10 (25.13)	5.26 (26.69)	5.73 (31.87)	5.85 (33.27)	10.76 (114.95)	10.98 (119.62)	0.00	0.00
LSD (p=0.05)	0.39	0.36	0.41	0.38	0.38	0.36	0.50	0.44	-	-

Data was subjected to square root transformation ($\sqrt{x+1}$). Original values are in parentheses

Table 4. Effect of weed management treatments on yield attributes and yield of direct-seeded basmati rice

Treatment	Grain yield (kg/ha)		Straw yield (kg/ha)		Gross returns (x10³ ₹/ha)		Cost of cultivation (x10³ ₹/ha)		Net returns (x10³ ₹/ha)		B: C ratio	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Pendimethalin1000 g/ha as PE	1.94	1.85	3.84	3.78	80.75	77.31	26.96	28.26	53.79	49.06	2.00	2.74
Pretilachlor 600 g/ha as PE	1.65	1.55	3.32	3.28	68.94	64.97	26.13	27.43	42.80	37.53	1.64	2.37
Oxyfluorfen 175 g/ha as PE	1.58	1.48	3.12	3.05	65.85	62.12	27.12	28.42	38.72	33.70	1.43	2.19
Bispyribac-sodium 25 g/ha at 25 DAS	2.12	2.03	4.31	4.27	88.51	85.26	27.31	28.61	61.20	56.65	2.24	2.98
Penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS	1.63	1.58	3.23	3.18	68.15	66.02	27.81	29.11	40.34	36.91	1.45	2.27
Fenoxaprop-p-ethyl + 2-4-D -EE (60+500 g/ha) at 25 DAS	1.80	1.76	3.53	3.49	75.07	73.31	27.82	29.12	47.26	44.20	1.70	2.52
Pendimethalin1000 g/ha *fb* bispyribac-sodium 25 g/ha at 25 DAS	2.67	2.57	5.52	5.48	111.87	107.91	29.61	30.91	82.27	77.00	2.78	3.49
Pretilachlor 600 g/ha *fb* penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS	2.45	2.39	4.91	4.86	102.38	99.99	29.28	30.58	73.09	69.41	2.50	3.27
Oxyfluorfen 175 g/ha *fb* fenoxaprop-p-ethyl + 2-4-D -EE (60+500 g/ha) at 25 DAS	2.07	2.00	3.85	3.79	86.01	83.18	30.28	31.58	55.73	51.59	1.84	2.63
Control	1.11	1.05	2.09	2.04	46.04	43.89	24.66	25.96	21.38	17.93	0.87	1.69
LSD (p=0.05)	0.31	0.29	0.69	0.68	-	-	-	-	-	-	-	-

fb penoxsulam + cyhalofop-butyl 150 g/ha at 25 DAS (**Table 4**). Singh *et al.* (2016) reported that in terms of the benefit cost ratio, the sequential application of pendimethalin as PE *fb* bispyribac-sodium + azimsulfuron as PoE was more cost-effective than the non-treated weed free treatment. Khaliq *et al.* (2012) also reported previously that post application of bispyribac-sodium increased rice grain yield and economic returns.

It was concluded that pendimethalin 1000 g/ha as PE *fb* bispyribac-sodium 25 g/ha or pretilachlor 600 g/ha *fb* penoxsulam + cyhalofop-butyl 150 g/ha found economical suitable for direct-seeded rice with more than 80% weed control efficiency.

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