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Bioefficacy of flucetosulfuron in wet-seeded rice

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ABSTRACT

Field experiments were conducted during rainy and winter seasons of 2016-17 in Kalliyoor Panchayat (8.4455^0 N and 76.9918^0 E), Nemom block, Thiruvananthapuram district, Kerala, India in order to assess the bioefficacy of flucetosulfuron in wet-seeded rice. The experiment was laid out in a randomised block design with 12 treatments and three replications. Flucetosulfuron 20, 25 and 30 g/ha applied at 2-3, 10-12 and 18-20 days after sowing (DAS) along with hand weeding at 20 and 40 DAS and weedy check comprised the treatments. Pooled analysis of the data for two seasons revealed the significance of time of application of flucetosulfuron in wet-seeded rice. Application of flucetosulfuron 25 g/ha at 10-12 DAS recorded the highest grain yield (8.33 t/ha), which was at par with flucetosulfuron 20 and 30 g/ha at 10-12 DAS and hand weeding at 20 and 40 DAS. Yield reduction due to weeds was found to be 52.33 and 55.61 per cent during rainy and winter seasons respectively. Higher yield attributes, harvest index, net income and B:C ratio were recorded for flucetosulfuron, applied at 10-12 and 18-20 DAS, irrespective of their dosage. The lower weed dry weight and weed index of these treatments substantiate the result. Henceforth, flucetosulfuron 20, 25 and 30 g/ha with a wide application window of 10-20 DAS can be endorsed for better weed management and higher yield in wet seeded rice.

INTRODUCTION

Rice (*Oryza sativa* L.), is traditionally grown by transplanting seedlings into puddled soil. Unavailability of labourers, higher labour cost and water scarcity lead farmers to adopt direct-seeded system of rice cultivation. Rice yields are affected by pests and among pests, weeds are one of the major constraints which affect rice productivity (Bhimwal and Pandey 2014). Weed management at critical period of crop growth is essential for obtaining higher yields. Hand weeding is an effective method but very expensive, time consuming and at early stages it is very difficult due to morphological similarities between grassy weeds and rice seedlings (Rahman *et al.* 2012). In large scale rice farming, herbicide-based weed management has become the smartest and most viable option due to scarcity and high wages of labour (Anwar *et al.* 2012). Despite some undesirable side effects, no viable alternative is presently available to shift the chemical dependence for weed management in rice (Juraimi *et al*. 2013). Continuous use of herbicides with similar mode of action might lead to development of resistance in certain weeds to herbicides. Hence, it is imperative to identify alternative herbicides for effective weed control and to ensure better crop yield (Gopinath and Kundu 2008). The efficacy of herbicide is evident, but ever mounting civic concern over the real or perceived impact of herbicides on public health and environment (Phuong *et al.* 2005) along with the risk of developing resistant weed biotypes (Heap 2006), phytotoxicity (Begum *et al.* 2008) and decline in soil microbial population (Ayansina and Osa 2006) has renewed the interest to alternate the use of herbicide molecules with different mode of action.

Flucetosulfuron is a pyrimidinyl sulfonylurea herbicide. It is a broad-spectrum systemic herbicide, inhibiting acetolactase synthase (ALS) enzyme, thus causing chlorosis of the plant, leading to death of apical meristems (Paranjape *et al.* 2014). Kim *et al.* (2003) observed that at the whole plant level, the GR 50 values (the dose rate required for 50% growth inhibition) of flucetosulfuron for *Echinochloa crus-galli* were 0.6 and 4.6 g/ha by soil and foliar application respectively, while those for rice were 183 and 223 g/ha respectively, demonstrating high activity of flucetosulfuron against *Echinochloa crus-galli* with good safety to rice. Flucetosulfuron is a new generation herbicide and identification of most ideal time of its application for season-long weed control in wet-seeded rice requires field investigation. Hence, the present study was undertaken.

MATERIALS AND METHODS

Field experiments were conducted during rainy and winter seasons of 2016-17 in Kalliyoor Panchayat (8.4455^0 N and 76.9918^0 E), Nemom block, Thiruvananthapuram district, Kerala, India. The experiment was laid out in a randomised block design with 12 treatments, *viz.* flucetosulfuron 20 g/ha at 2-3 DAS, flucetosulfuron 25 g/ha at 2-3 DAS, flucetosulfuron 30 g/ha at 2-3 DAS, flucetosulfuron 20 g/ha at 10-12 DAS, flucetosul-furon 25 g/ha at 10-12 DAS, flucetosulfuron 30 g/ha at 10-12 DAS, flucetosulfuron 20 g/ha at 18-20 DAS, flucetosulfuron 25 g/ha at 18-20 DAS, flucetosulfuron 30 g/ha at 18-20 DAS, bispyribac-sodium 25 g/ha at 15 DAS, hand weeding at 20 and 40 DAS and weedy check. The treatments were replicated thrice. Short duration rice variety Kanchana (*PTB 50*) was selected as test crop which was released from Regional Agricultural Research Station, Pattambi, Kerala and the gross and net plot size were 5 x 4 m and 4.7 x 3.7 m, respectively.

Seeds were sown at 100 kg/ha after soaking in water for 24 h and keeping under shade in gunny bag for sprouting. Crop was raised based on the agronomic management practices as per Kerala Agricultural University package of practices recommendations (KAU 2011). Herbicide was applied using knapsack sprayer fitted with flood-jet nozzle. Rainy and winter crop durations were 105 and 107 days respectively. Data on rice yield attributes were recorded from 10 randomly selected plants from each plot. Productive tillers/m^2 were counted from two randomly selected sites from each plot and averaged. A random sample of spikelets were taken from the produce of each plot, 1000 spikelets were counted manually and weighed on an electronic balance. Crop was harvested and tied into bundles from the net area in respective plots, threshed, sundried and weight of grain and straw were recorded.

Data on weed dry weight was recorded at 15, 30, 45, and 60 DAS from two randomly selected quadrats (100 x 100 cm) from each experimental plot. Weeds were uprooted from ground surface, and dried in an oven at 70 ºC for determining dry weed biomass.

All the data were subjected to Analysis of Variance techniques (ANOVA) after transformation wherever needed.

RESULTS AND DISCUSSION

Weed dry weight

The weed flora in the experiment field included grasses, *viz.* *Isachne miliacea* Roth ex Roem. Et Schult, *Echinochloa colona* (L.) Link, *Echinochloa crusgalli* (L.) P. Beauv., broad-leaved weeds, *viz.* *Limnocharis flava* (L.) Buchenau., *Monochoria vaginalis* (Burm.f.) C. Presl ex Kunth, *Ludwigia perennis* L., *Marselia quadrifolia* L. and sedges *Schoenoplectus juncoides* (Roxb.) Palla, *Fimbristylis miliaceae* (L.) Vahl., *Cyperus iria* L., and *Cyperus haspen* L.

During rainy season at 15 DAS, flucetosulfuron 25 g/ha applied at 10-12 DAS recorded the lowest weed dry weight and was found to be on par with the highest and the lowest doses of flucetosulfuron at 10-12 DAS (**Figure 1**) while during winter season the lowest weed dry weight was recorded when flucetosulfuron 20 g/ha was applied at 10-12 DAS which remained on par with application of flucetosulfuron 20, 25 and 30 g/ha at 2-3 DAS and also with application of flucetosulfuron 25 and 30 g/ ha at 10-12 DAS (**Figure 2**). The lower weed dry weight in these treatments may be the effect of these treatments on weeds at 15 DAS. However, at 30 DAS during rainy season the highest dose of flucetosulfuron at 18-20 DAS recorded the lowest total weed dry weight and the treatments, *viz*. flucetosulfuron 30 g/ha at 10-12 DAS and flucetosulfuron 20 g/ha at 18-20 DAS were found to be comparable. Also, it was found that flucetosulfuron 25 g/ha at 10-12 DAS was on par with its application 30 g/ha at 10-12 DAS and flucetosulfuron 20 and 25 g/ha at 18-20 DAS. During winter season the lowest weed dry weight was recorded when flucetosulfuron 25 g/ha was applied at 18-20 DAS which was on par with 20 and 30 g/ha at 18-20 DAS. These were followed by flucetosulfuron 20, 25 and 30 g/ha at 10-12 DAS and application of the lowest dose of flucetosulfuron at 10-12 DAS remained on par with the same dosage at 18-20 DAS. At 45 DAS, during rainy season, hand weeding twice recorded the lowest weed dry weight followed by the application of flucetosulfuron 30 g/ha at 18-20 DAS. Whereas, during winter season the lowest weed dry weight was recorded by flucetosulfuron 20 g/ha at 18-20 DAS and was on par with 30 g/ha applied at 18-20 DAS and hand weeding twice. At 60 DAS, during rainy season, hand weeding twice recorded the lowest weed dry weight and was found to be on par with application of flucetosulfuron 20, 25 and 30 g/ha at 10-12 DAS and 18-20 DAS. During winter season also hand weeding twice recorded the lowest

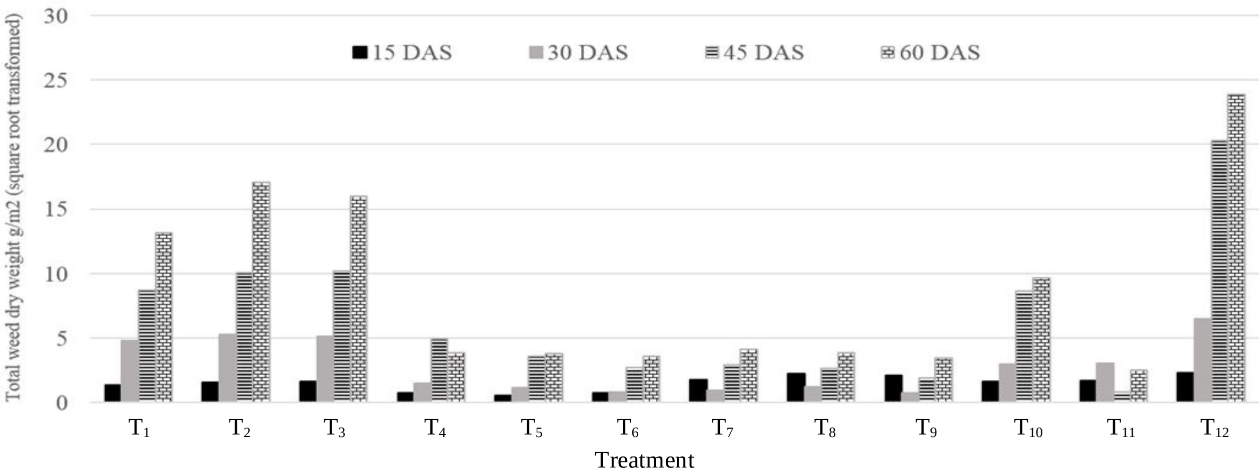
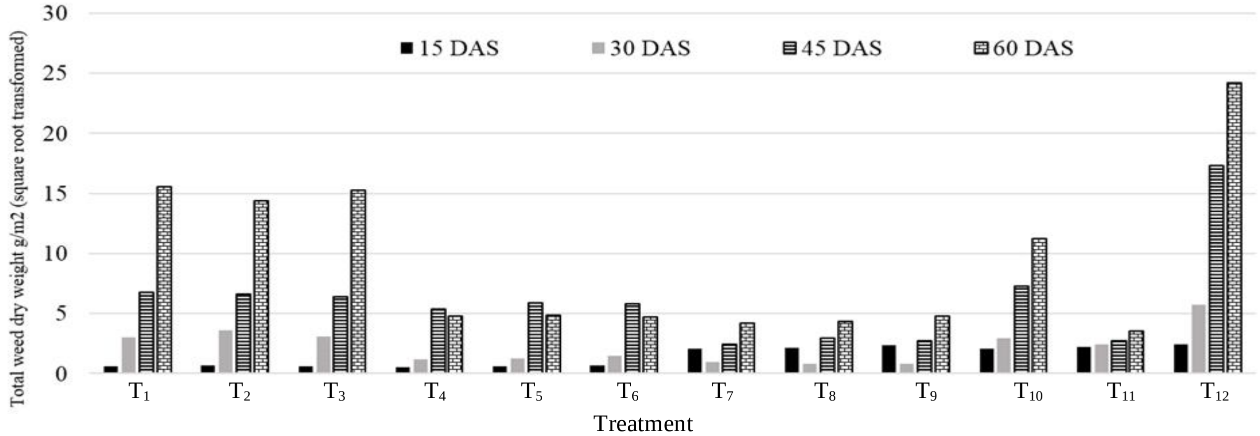


Figure 1. Effect of weed management practices on total weed dry weight during rainy season



T_1 - Flucetosulfuron 20 g/ha at 2-3 DAS; T_2 - Flucetosulfuron 25 g/ha at 2-3 DAS; T_3 - Flucetosulfuron 30 g/ha at 2-3 DAS; T_4 - Flucetosulfuron 20 g/ha at 10-12 DAS; T_5 - Flucetosulfuron 25 g/ha at 10-12 DAS; T_6 - Flucetosulfuron 30 g/ha at 10-12 DAS; T_7 - Flucetosulfuron 20 g/ha at 18-20 DAS; T_8 - Flucetosulfuron 25 g/ha at 18-20 DAS; T_9 - Flucetosulfuron 30 g/ha at 18-20 DAS; T_{10} - Bispyribac-sodium 25 g/ha at 15DAS; T_{11} - Hand weeding at 20 and 40 DAS; T_{12} - Weedy check

Figure 2. Effect of weed management practices on total weed dry weight during winter season

weed dry weight. This was followed by application of flucetosulfuron 20 and 25 g/ha at 18-20 DAS which remained on par with 20 and 30 g/ha applied at 10-12 DAS along with flucetosulfuron 30 g/ha at 18-20 DAS. Weedy check recorded significantly higher total weed dry weight for both the seasons (**Figure 1** and **2**). Similar results were reported by Bhimwal and Pandey (2014).

Here it is obvious that effect of flucetosulfuron applied at 2-3 DAS did not last for more than 15 DAS while the effect of flucetosulfuron applied at 10-12 DAS showed good weed control efficacy even in later stages. Lower weed dry weight was observed with plots where flucetosulfuron was applied at 10-12 and 18-20 DAS irrespective of dose of application, during the critical crop growth stages. Even though herbicide was applied at 10-12 DAS, those treatments could maintain a lower weed dry weight even at 60 DAS along with herbicide applied at 18-20 DAS. This may be the reason for higher grain yield in plots where the herbicide was applied at 10-12 DAS and 18-20 DAS. Herbicide treatments were effective in reducing weed biomass by more than 75% on an average (Singh *et al.* 2016). However, application of bispyribac sodium 25 g/ha at 15 DAS resulted in significantly higher weed dry weight compared to flucetosulfuron applied at 10-12 DAS and 18-20 DAS during critical stages of crop growth. This may be the reason for lower grain yield and yield attributes associated with this treatment.

Yield attributes and yield

Productive tillers/m^2 varied significantly due to the treatments (**Table 1**). During rainy season, the highest number of productive tillers was recorded by hand weeding at 20 and 40 DAS and it was on par with application of flucetosulfuron 20, 25 and 30 g/ha at 10-12 DAS and 18-20 DAS. However during winter season, flucetosulfuron 20 g/ha at 18-20 DAS recorded the highest number of productive tillers/m^2 and it was found to be on par with flucetosulfuron 20, 25 and 30 g/ha applied at 10-12 DAS and flucetosulfuron 25 and 30 g/ha applied at 18-20 DAS along with hand weeding at 20 and 40 DAS. The lowest number of productive tillers/m^2 was recorded by weedy check during both the seasons.

Flucetosulfuron 25 g/ha at 10-12 DAS recorded the highest number of spikelets/panicle (99.89) and was found to be on par with hand weeding at 20 and 40 DAS, flucetosulfuron 20 g/ha at 10-12 DAS and flucetosulfuron 25 g/ha at 18-20 DAS during rainy season while during winter season hand weeding at 20 and 40 DAS recorded the highest number of spikelets/panicle (106.78) and remained on par with flucetosulfuron 20, 25 and 30 g/ha at 10-12 DAS and 18-20 DAS. The lowest sterility percentage (12.75) was recorded by flucetosulfuron 30 g/ha at 10-12 DAS and was on par with flucetosulfuron 20 and 25 g/ha at 10-12 DAS and flucetosulfuron 20, 25 and 30 g/ha at 18-20 DAS along with hand weeding at 20 and 40 DAS during rainy season. However, during winter season, flucetosulfuron 20 g/ha at 10-12 DAS recorded the lowest percentage of spikelet sterility and was on par with all the treatments in which flucetosulfuron was applied at 10-12 and 18-20 DAS along with hand weeding at 20 and 40 DAS (**Table 1**).

Significantly higher grain yield was obtained with flucetosulfuron applied at 10-12 and 18-20 DAS along with hand weeding twice (**Table 2**). During rainy season, the highest grain yield (8.10 t/ha) was recorded by flucetosulfuron 25 g/ha at 10-12 DAS which was found to be on par with hand weeding at 20 and 40 DAS. The treatments, *viz.* flucetosulfuron 30 g/ha at 10-12 DAS, flucetosulfuron 20 g/ha at 18-20 DAS and flucetosulfuron 20 g/ha at 10-12 DAS were found to be at par with hand weeding twice. During winter season, flucetosulfuron 20 g/ha at 10-12 DAS recorded the highest grain yield (8.94 t/ha) and was at par with flucetosulfuron 25 and 30 g/ha at 10-12 DAS, flucetosulfuron 30 g/ha at 18-20 DAS and hand weeding at 20 and 40 DAS. Yield reduction due to weeds was found to be 52.33 and 55.61 per cent during rainy and winter seasons respectively. The results are in conformity with the finding of Bhimwal and Pandey (2014) who reported that flucetosulfuron 10 WG 25 g/ha applied at 2 days after transplanting recorded higher yield. Critical evaluation of the data could reveal that bispyribac sodium 25 g/ha at 15 DAS recorded significantly lower grain yield because of its poor efficacy in controlling the major weed *Schoenoplectus juncoides*.

The highest grain yield of 8.33 t/ha was recorded by flucetosulfuron 25 g/ha at 10-12 DAS and was found to be on par with hand weeding twice, and flucetosulfuron 20 g and 30 g/ha at 10-12 DAS **(Table 2)**.

Weed index and economics

Hand weeding twice recorded the lowest weed index (1.84) during rainy season, which was followed by flucetosulfuron 30 g/ha at 10-12 DAS and this was found to be on par with application of flucetosulfuron 20 g/ha at 10-12 and 18-20 DAS and flucetosulfuron 25 g/ha at 18-20 DAS (**Table 1**). During winter season, flucetosulfuron 25 g/ha at 10-12 DAS recorded the lowest weed index (4.29) and was found to be comparable with application of flucetosulfuron 30 g/ha at 10-12 DAS, flucetosul-

Table 1. Effect of weed management treatments on productive tillers/m^2, spikelets/panicle, sterility percentage, 1000 grain weight and weed index

Treatment	Productive tillers/ m^2		Spikelets /panicle		Sterility percentage (%)		1000-grain weight (g)		Weed index	
	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
Flucetosulfuron 20 g/ha at 2-3 DAS	316.9	306.1	88.7	98.4	20.5	15.4	29.5	30.0	5.56 (30.45)	3.99(15.81)
Flucetosulfuron 25 g/ha at 2-3 DAS	309.7	299.2	89.9	99.2	20.7	16.6	28.9	30.4	5.81 (33.31)	4.20(17.14)
Flucetosulfuron 30 g/ha at 2-3 DAS	312.2	311.4	87.0	99.3	20.8	15.9	29.3	30.6	5.97 (35.38)	3.87(14.74)
Flucetosulfuron 20 g/ha at 10-12 DAS	435.8	451.4	98.7	103.7	14.9	10.8	29.4	31.0	3.04 (9.52)	0.701 (0)
Flucetosulfuron 25 g/ha at 10-12 DAS	450.3	416.5	99.9	103.9	13.3	12.7	29.5	30.8	0.701 (0)	1.96 (4.29)
Flucetosulfuron 30 g/ha at 10-12 DAS	450.6	415.6	95.9	106.3	12.7	12.2	29.5	31.2	2.86 (8.21)	2.08 (4.22)
Flucetosulfuron 20 g/ha at 18-20 DAS	486.1	454.4	96.2	104.3	14.9	11.8	29.5	30.8	3.03 (8.88)	2.76 (7.62)
Flucetosulfuron 25 g/ha at 18-20 DAS	433.5	433.2	97.3	104.9	15.3	12.0	29.7	30.7	3.77 (13.89)	2.91 (8.19)
Flucetosulfuron 30 g/ha at 18-20 DAS	449.1	438.1	96.6	102.3	15.1	12.5	29.2	31.0	4.04 (16.35)	2.26 (5.33)
Bispyribac sodium 25 g/ha at 15DAS	327.9	280.0	89.3	98.3	20.4	15.6	29.2	31.0	5.29 (27.66)	4.39(18.88)
Hand weeding at 20 and 40 DAS	504.8	394.9	99.6	106.8	14.3	12.9	29.6	31.4	1.50 (1.84)	2.27 (4.76)
Weedy check	294.2	267.4	80.8	91.3	24.8	21.1	28.4	30.5	7.26 (52.33)	7.50(55.61)
LSD (p=0.05)	103.2	91.5	3.3	4.4	4.20	2.2	NS	NS	1.16	1.15

Note: The data on weed index were subjected to square root transformation ($\sqrt{x+0.5}$) and the values given in parentheses are original, DAS=days after sowing

Table 2. Effect of weed management treatments on grain yield, straw yield, harvest index, net returns and B:C ratio

Treatment	Grain yield (t/ha)			Straw yield (t/ha)			Harvest index		Net returns ($x10^3$ `/ha)		B:C Ratio	
	Rainy	Winter	Pooled	Rainy	Winter	Pooled	Rainy	Winter	Rainy	Winter	Rainy	Winter
Flucetosulfuron 20 g/ha at 2-3 DAS	5.63	7.53	6.58	7.20	8.07	7.63	0.44	0.48	98.07	158.34	1.84	2.35
Flucetosulfuron 25 g/ha at 2-3 DAS	5.40	7.41	6.40	8.20	7.42	7.81	0.40	0.50	99.24	149.38	1.84	2.27
Flucetosulfuron 30 g/ha at 2-3 DAS	5.24	7.63	6.43	8.00	7.96	7.98	0.40	0.49	92.70	159.30	1.79	2.35
Flucetosulfuron 20 g/ha at 10-12 DAS	7.33	8.94	8.14	9.23	7.56	8.40	0.44	0.54	162.06	193.90	2.38	2.66
Flucetosulfuron 25 g/ha at 10-12 DAS	8.10	8.56	8.33	8.13	7.89	8.01	0.50	0.52	174.30	185.33	2.48	2.58
Flucetosulfuron 30 g/ha at 10-12 DAS	7.44	8.57	8.00	7.53	7.46	7.49	0.50	0.53	150.54	181.62	2.28	2.54
Flucetosulfuron 20 g/ha at 18-20 DAS	7.38	8.26	7.82	8.57	8.07	8.32	0.46	0.51	158.08	178.85	2.35	2.53
Flucetosulfuron 25 g/ha at 18-20 DAS	6.98	8.21	7.59	8.50	8.68	8.59	0.45	0.49	145.84	181.89	2.24	2.55
Flucetosulfuron 30 g/ha at 18-20 DAS	6.77	8.47	7.62	7.87	7.74	7.81	0.47	0.52	134.49	181.13	2.14	2.54
Bispyribac sodium 25 g/ha at 15DAS	5.86	7.26	6.56	9.17	8.21	8.69	0.39	0.47	119.31	150.85	2.01	2.28
Hand weeding at 20 and 40 DAS	7.95	8.52	8.23	8.90	8.18	8.54	0.47	0.51	149.32	159.53	2.03	2.10
Weedy check	3.86	3.97	3.91	7.90	7.60	7.75	0.33	0.35	59.84	60.57	1.54	1.54
LSD (p=0.05)	0.63	0.51	0.43	NS	NS	0.91	0.05	0.04	20.94	17.58	0.17	0.14

DAS=days after sowing

furon 20, 25 and 30 g/ha at 18-20 DAS along with hand weeding twice. Higher weed index was reported by weedy check during both the seasons followed by application of bispyribac sodium 25 g/ha at 15 DAS.

During rainy season, flucetosulfuron 25 g/ha at 10-12 DAS recorded the highest net returns (174.30 $x10^3$ `/ha) which was on par with flucetosulfuron 20 g/ha at 10-12 DAS and 18-20 DAS and these were again at par with flucetosulfuron 30 g/ha at 10-12 DAS, flucetosulfuron 25 g/ha and 30 g/ha at 18-20 DAS along with hand weeding twice (**Table 2**). During winter season, the highest net returns was recorded by flucetosulfuron 20 g/ha at 10-12 DAS and was found to be on par with flucetosulfuron 25 and 30 g/ha at 10-12 DAS and flucetosulfuron 20, 25 and 30 g/ha at 18-20 DAS. Similar results were obtained for B:C ratio also. Based on the results, it was concluded that flucetosulfuron 25 g/ha applied at 10-12 DAS effectively controlled the weeds and recorded the highest grain yield and monetary benefits in wet-seeded rice.

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