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Effect of herbicides on weed dynamics, yield and monetary returns of rice (*Oryza sativa* L.)

Preeti Singh, Vivek, Pooja Singh and Akshay Ujjawal

Abstract
A field study was conducted during the *Kharif* season of 2021 at Crop Research Center, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, (U.P.), to assess the performance of post-emergence application of Bispyribac sodium & Penoxsulam in combination with pre-emergence application of Ethoxy Sulfuron & Oxidiargyl on rice. The treatments comprised of Control (Weedy check) T_1, Weed free T_2, Bispyribac sodium @ 25g a.i ha^{-1} T_3, Penoxsulam @ 20g a.i.ha^{-1} T_4, Penoxsulam @ 25g a.i.ha^{-1} T_5, Penoxsulam @ 30 g a.i.ha^{-1} T_6, Oxidiargyl @ 80g a.i.ha^{-1} T_7, Oxidiargyl @ 100g a.i.ha^{-1} T_8, Oxidiargyl @ 120g a.i.ha^{-1} T_9, Ethoxy Sulfuron @ 20g a.i.ha^{-1}T_{10}, Ethoxy Sulfuron @ 25g a.i.ha^{-1} T_{11} and Ethoxy Sulfuron @ 30g a.i.ha^{-1} T_{12}. Treatments effect were evaluated in terms of weed dynamics growth and yield of rice. The results revealed that the maximum weed control efficiency at 90 DAT in Ethoxy Sulfuron @ 30g a.i.ha^{-1} T_{12} was found at par with Ethoxy Sulfuron @ 25g a.i.ha^{-1} T_{11} and Ethoxy Sulfuron @ 20g a.i.ha^{-1} T_{10} and significantly higher than the rest of treatments. The results also revealed that among the different herbicides, the highest grain yield (45.7 q ha^{-1}) was obtained under weed free treatment which was statistically at par with (23.7 q ha^{-1}) Ethoxy Sulfuron @ 30g a.i.ha^{-1} T_{12}. The results revealed that the highest net monetary returns (₹ 59890 ha^{-1}) and B:C ratio (2.27) among all the treatments was obtained with weed free treatment while among herbicidal treatments the highest net monetary return (₹ 59752 ha^{-1}) and B:C ratio (2.43) was obtained with Ethoxy Sulfuron @ 30g a.i.ha^{-1} followed by Ethoxy Sulfuron @ 25g a.i.ha^{-1}. The Ethoxy Sulfuron @ 30g a.i.ha^{-1} pre-emergence found better for higher productivity and profitability of rice crop due to the high efficacy of Ethoxy Sulfuron.

Keywords: Rice, herbicide, weed dynamics, productivity, profitability

Introduction
Rice (*Oryza sativa* L.) is a monocot plant belongs to the grass family Poaceae. For proper growth, rice plant needs both warm and moist environment. It is major staple crop of the world to diet of 2.7 billion people and it contains 6-9% protein, 3% fat and 3% fiber.

In the world, it is occupying 163.26 million hectare of area, producing 757 million tonnes of rice with an average productivity of 4.41 tonnes ha^{-1} (Anonymous, 2020) [2]. In India, during 2020-21 rice was cultivated in 44.5 million hectare area with an annual production of 122.27 million tonnes and average productivity of 2.86 tonnes ha^{-1}. In Uttar Pradesh, rice was cultivated on 5.87 million hectare area with the production of 15.52 million tones and the productivity of 2.63 tonnes ha^{-1} in 2020-21. Uttar Pradesh occupied 13.65 and 11.81 percent share in area and production of rice in the country, respectively.

Effective weed control in transplanted rice is one of the major limitations. Manual removal of weeds is labour intensive, tedious, back-breaking, cumbersome and costly alternative. The chemical method of weed management is best suited as it takes care of weeds right from beginning of crop growth and cost effective. However, to have minimum competition between weeds and rice the weeds need to be kept below threshold level especially during critical weed competition period. Among all the herbicides for control of *Echinochloa crusgalli* Ethoxy Sulfuron @ 30g a.i.ha^{-1} was the best while Bispyribac sodium @ 25g a.i ha^{-1} was quite good against sedges (Yadav *et al*., 2011) [21]. Water management is an important component of any weed control program, whether any herbicide is used or not. Herbicides which give excellent control when applied into water may perform poorly in the absence of standing water (Kumar *et al*., 2009). Integrated use of herbicide Ethoxy Sulfuron, Oxidiargyl or Penoxsulam along with closer planting was effective for reducing weed Population and dry weight (Gogoi *et al*. 2005) [4]. The herbicide Ethoxy Sulfuron has both foliar and soil activity (Rajkhowa *et al*., 2006) [17]. It is generally recommended as a pre emergence herbicide in transplanted rice (Angiras and Kumar 2005) [1].

Studies on bio efficacy and phytotoxicity of Ethoxy Sulfuron for pre-emergence weed control in transplanted rice are scanty and there are different reports of various dosages and time of application required for effective weed control (Chopra and Chopra 2003) [3]. Penoxsulam is a post emergence herbicide, used as broad spectrum weed control of grasses, broad leaves and annual sedges, with excellent control of *Echinochloa species*. Reduction in weed density due to application of Ethoxy Sulfuron in transplanted rice were reported by Yadav *et al*. (2009) [20].

Hence, use of herbicides in conjunction with manual practices would make the herbicidal control more acceptable to farmers. Application of selective herbicides may control certain species or group of weeds and may not be effective on other weed species. In such situation, while one group of weeds is effectively eliminated, the other group takes over and offers severe competition to the crop. Herbicides with differential selectivity can be applied sequentially, but it results in enhancing the cost. Therefore, mixing two different herbicides and applying them simultaneously widens the spectrum of weed-control, saves time and application cost.

Materials and Methods

The field experiment was conducted at CRC farm of the Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.). The soil of experimental site was sandy loam in texture, low in available nitrogen and organic carbon content (0.40%), medium in available phosphorus and potassium and slightly alkaline in reaction. The gross and net plot size were 5.0 x 4.0 m^2 and 4.0 x 3.2 m^2, respectively. Experiment was laid out randomized block design with three replications. Twelve weed management treatments [Weedy check, weed free, Bispyribac sodium @ 25g a.i ha^{-1} (PoE), Penoxsulam @ 20 g a.i.ha^{-1} (PoE), Penoxsulam @ 25 g a.i.ha^{-1} (PoE), Penoxsulam @ 30 g a.i.ha^{-1} (PoE), Oxidiargyl @ 80 g a.i.ha^{-1} (PE), Oxidiargyl @ 100g a.i.ha^{-1} (PE), Oxidiargyl @ 120g a.i.ha^{-1} (PE), Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE), Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) and Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE)] were used for the experimentation. To ensure proper germination, field was prepared after pre-sowing irrigation and subsequent irrigation was given as per requirement. The inter-row spacing and intra-row spacing was maintained at 20 cm and 10 cm respectively. Economics of treatments was computed on the basis of prevailing market price of inputs and outputs under each treatment. The total cost of cultivation of crop was calculated on the basis of different operations performed and materials used for raising the crop including the cost of fertilizers and seeds. The cost of labour incurred in performing different operations was also included. Statistical analysis of the data was done as per the standard analysis of variance technique for the experimental designs following SPSS software based program, and the treatment means were compared at $P<0.05$ level of probability using t-test and calculating CD values.

Results and Discussion

Influence of herbicides on weeds

Density of total weeds was affected significantly by various treatments involving weed management practices. Among weed control treatments, the highest total weed density (19.7, 20.5 and 18.7 m^{-2}) was found under weedy check treatment, at 30, 60 and 90 DAT, respectively.

Table 1: Effect of herbicides on density of total weed density (m^{-2}) at different stages

Treatments		Total weed density (m^{-2})		
		30 DAT	60 DAT	90 DAT
T_1	Weedy check	19.7(386.9)	20.5(420.0)	18.7(349.6)
T_2	Weed free	0.5(0.0)	0.5(0.0)	0.5(0.0)
T_3	Bispyribac sodium @ 25g a.i ha^{-1} (PoE)	11.4(129.7)	9.8(95.9)	9.1(82.0)
T_4	Penoxsulam @ 20 g a.i.ha^{-1} (PoE)	11.7(136.3)	12.5(156.1)	11.9(140.8)
T_5	Penoxsulam @ 25 g a.i.ha^{-1} (PoE)	11.6(134.3)	12.2(147.8)	11.5(132.3)
T_6	Penoxsulam @ 30 g a.i.ha^{-1} (PoE)	11.5(131.9)	11.7(137.0)	11.1(122.1)
T_7	Oxidiargyl @ 80 g a.i.ha^{-1} (PE)	10.3(105.8)	11.4(128.4)	10.7(113.9)
T_8	Oxidiargyl @100g a.i.ha^{-1} (PE)	9.3(85.3)	10.4(107.1)	9.8(96.4)
T_9	Oxidiargyl @120g a.i.ha^{-1} (PE)	9.6(91.8)	10.9(118.7)	10.3(105.8)
T_{10}	Ethoxy Sulfuron @20g a.i.ha^{-1} (PE)	8.7(75.1)	9.3(86.1)	8.7(74.6)
T_{11}	Ethoxy Sulfuron @25g a.i.ha^{-1} (PE)	7.9(62.0)	8.8(76.7)	8.2(66.9)
T_{12}	Ethoxy Sulfuron @30g a.i.ha^{-1} (PE)	7.3(52.1)	7.9(62.5)	7.5(55.9)
	SEm+	0.37	0.39	0.36
	C.D.(P=0.05)	1.10	1.11	1.04

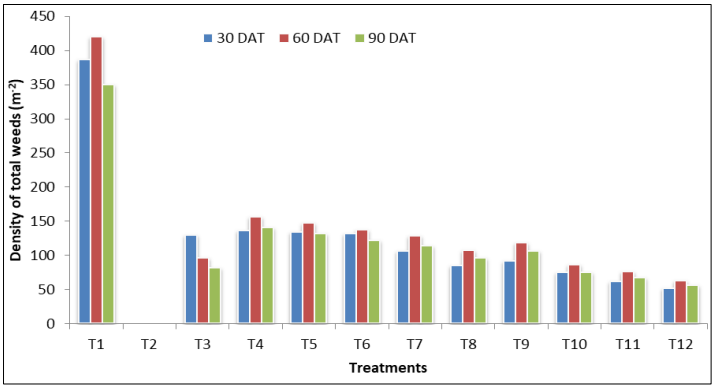

Fig 1: Effect of herbicides on density of total weed density (m^{-2}) at different stages

Among all the treatments except weed free, the lowest total weed density was observed (7.3 m^{-2}) in the treatment of Ethoxy Sulfuron @30g a.i.ha^{-1} (PE), at 30 DAT. At 60 and 90 DAT the lowest total weed density (7.9 m^{-2} & 7.5 m^{-2}) was observed with the application of Ethoxy Sulfuron @30g a.i.ha^{-1} (PE), which was found statistically at par with Ethoxy Sulfuron @25g a.i.ha^{-1} (PE) (8.8 & 8.2 m^{-2}) and Ethoxy Sulfuron @20g a.i.ha^{-1} (PE) (9.3 & 8.7 m^{-2}) at 60 and 90 DAT, respectively.

Total weed dry weight was affected significantly by various treatments involving weed management practices. Among weed control treatments, significantly the highest total weed dry weight (9.6, 13.8 & 15.3 g m^{-2}) was found in weedy check while the lowest total dry weight (0.5, 0.5 & 0.5 g m^{-2}) was found in weed free treatment at 30, 60 and 90 DAT. This was due to the fact that at later stage most of the weed growth ceased because of leaf senescence, and thereby resulted in reduction in dry matter accumulation of weeds. Higher infestation of weeds under weedy check were also reported by Prameela *et al*. (2014) [15].

Table 2: Effect of herbicides on weed dry weight total weeds (g m^{-2}) at different stages

Treatments		Weed dry weight of total weeds (g m^{-2})		
		30 DAT	**60 DAT**	**90 DAT**
T_1	Weedy check	9.6(92.0)	13.8(190.5)	15.3(234.7)
T_2	Weed free	0.5(0.0)	0.5(0.0)	0.5(0.0)
T_3	Bispyribac sodium @ 25g a.i ha^{-1} (PoE)	6.8(46.0)	8.0(64.0)	8.9(78.1)
T_4	Penoxsulam @ 20 g a.i.ha^{-1} (PoE)	7.1(50.4)	10.2(102.6)	10.9(117.4)
T_5	Penoxsulam @ 25 g a.i.ha^{-1} (PoE)	7.1(49.3)	10.1(100.9)	10.7(115.0)
T_6	Penoxsulam @ 30 g a.i.ha^{-1} (PoE)	7.0(48.1)	9.9(97.6)	10.5(110.3)
T_7	Oxidiargyl @ 80 g a.i.ha^{-1} (PE)	6.8(45.9)	9.7(93.5)	10.3(105.6)
T_8	Oxidiargyl @100g a.i.ha^{-1} (PE)	5.9(34.1)	8.6(73.1)	9.0(80.0)
T_9	Oxidiargyl @120g a.i.ha^{-1} (PE)	6.3(39.5)	9.5(90.1)	10.2(104.1)
T_{10}	Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE)	5.4(28.2)	7.8(60.4)	8.7(75.0)
T_{11}	Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE)	5.1(25.7)	7.6(57.1)	8.5(72.2)
T_{12}	Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE)	5.0(24.5)	7.1(49.5)	8.0(62.8)
	SEm+	0.21	0.31	0.34
	C.D.(P=0.05)	0.60	0.90	0.98

Original values in parenthesis. Values are square root $\sqrt{X + 0.50}$

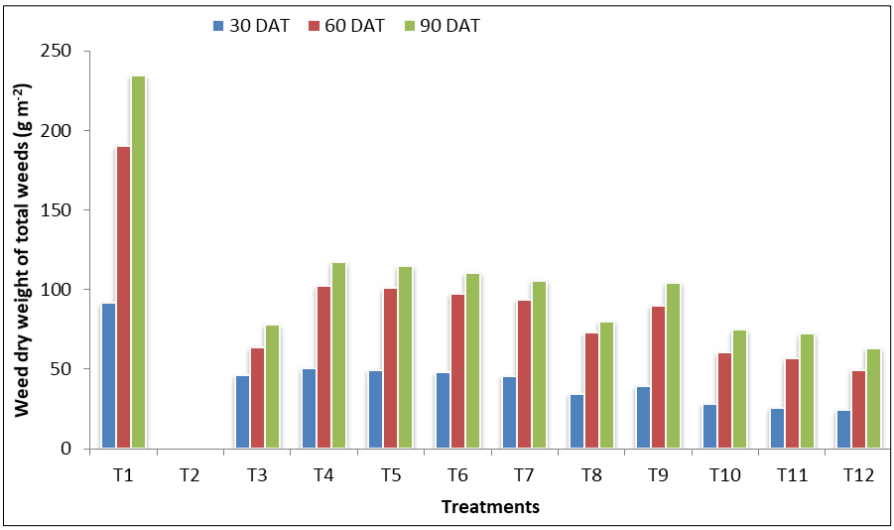

Fig 2: Effect of herbicides on weed dry weight total weeds (g m^{-2}) at different stages

Among the herbicides at 30 DAT the total dry weight observed (5.0 g m^{-2}) was lowest with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) than rest of the treatments. At 60 DAT total dry weight observed (7.1 g m^{-2}) was significantly lowest with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE), which was statistically at par with Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (7.6 and 7.8 g m^{-2}). Significantly lower total dry weight at 90 DAT (8.0 g m^{-2}) observed with the application of Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) was found at par with Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (8.5 and 8.7 g m^{-2}) and significantly lower than the remaining treatments.

Weed control efficiency (WCE)

Weed control efficiency was affected significantly by various treatments involving weed management practices. Among weed control treatments significantly the highest weed control efficiency (100.0 %) was found in weed free at 90 DAT. Among the herbicides highest weed control efficiency (73.2 %) with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) followed by Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (69.2%) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (68.0%) at 90 DAT, respectively. This result is in corroboration with the findings of Duary *et al.* (2015).

Table 3: Effect of herbicides on weed control efficiency (%) at 90 Days

Treatments		Weed control efficiency (%)
T_1	Weedy check	0.0
T_2	Weed free	100.0
T_3	Bispyribac sodium @ 25g a.i ha^{-1} (PoE)	66.7
T_4	Penoxsulam @ 20 g a.i.ha^{-1} (PoE)	49.9
T_5	Penoxsulam @ 25 g a.i.ha^{-1} (PoE)	51.0
T_6	Penoxsulam @ 30 g a.i.ha^{-1} (PoE)	53.0
T_7	Oxidiargyl @ 80 g a.i.ha^{-1} (PE)	55.0
T_8	Oxidiargyl @ 100g a.i.ha^{-1} (PE)	65.9
T_9	Oxidiargyl @ 120g a.i.ha^{-1} (PE)	55.6
T_{10}	Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE)	68.0
T_{11}	Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE)	69.2
T_{12}	Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE)	73.2
	S Em+	2.1
	C.D.(P=0.05)	6.2

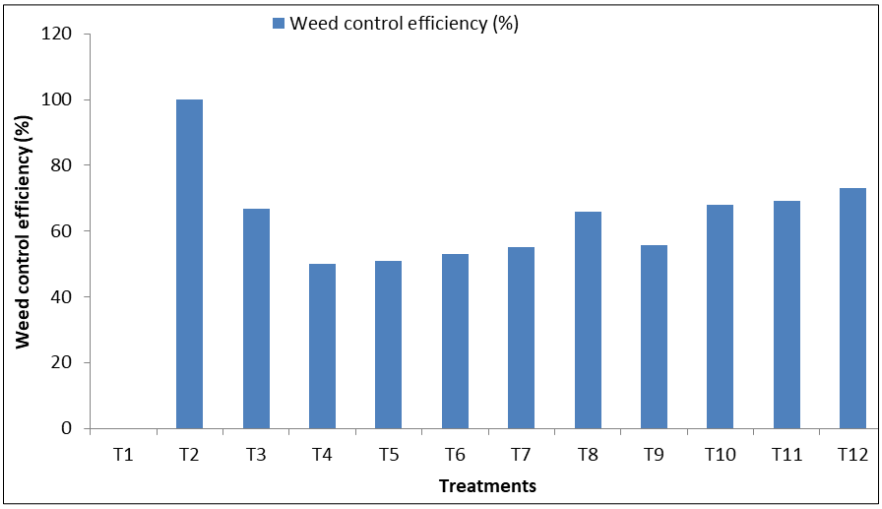

Fig 3: Effect of herbicides on weed control efficiency (%) at 90 Days

Influence on yield parameters of rice

Panicle length (cm) was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest panicle length (20.9 cm) was found in weedy check which was significantly lower than the remaining treatments. The highest panicle length (26.7 cm) was found in weed free which was significantly higher than other treatments.

Table 4: Effect of herbicides on yield attributes of rice

	Treatments	Yield attributes			
		Panicle length (cm)	Filled grains $panicle^{-1}$	Unfilled grains $panicle^{-1}$	1000 grains weight (g)
T_1	Weedy check	20.9	82.9	35.3	19.7
T_2	Weed free	26.7	115.8	44.5	20.3
T_3	Bispyribac sodium @ 25g a.i ha^{-1} (PoE)	24.3	107.5	40.7	20.1
T_4	Penoxsulam @ 20 g a.i.ha^{-1} (PoE)	22.1	97.8	37.3	19.8
T_5	Penoxsulam @ 25 g a.i.ha^{-1} (PoE)	22.3	98.3	37.9	19.8
T_6	Penoxsulam @ 30 g a.i.ha^{-1} (PoE)	22.8	100.0	39.0	19.9
T_7	Oxidiargyl @ 80 g a.i.ha^{-1} (PE)	22.9	100.6	40.3	19.9
T_8	Oxidiargyl @100g a.i.ha^{-1} (PE)	24.3	105.5	40.7	20.1
T_9	Oxidiargyl @120g a.i.ha^{-1} (PE)	23.0	100.8	40.4	19.9
T_{10}	Ethoxy Sulfuron @20g a.i.ha^{-1} (PE)	24.7	109.8	40.8	20.2
T_{11}	Ethoxy Sulfuron @25g a.i.ha^{-1} (PE)	24.8	110.2	41.7	20.2
T_{12}	Ethoxy Sulfuron @30g a.i.ha^{-1} (PE)	24.9	110.9	42.6	20.3
	SEm (±)	0.8	3.7	1.4	0.7
	C.D. (P=0.05)	2.4	10.6	4.1	NS

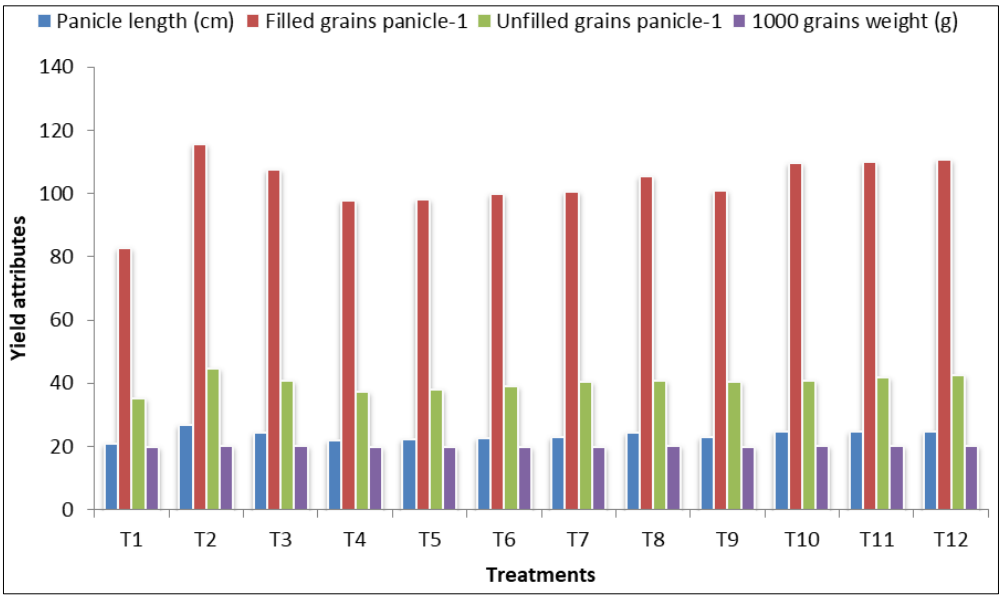

Fig 4: Effect of herbicides on yield attributes of rice of rice

Among the herbicides, the highest panicle length (24.9 cm) was recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) which was at par with Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE), Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE), Oxidiargyl @ 100g a.i.ha^{-1} (PE) and Oxidiargyl @ 120g a.i.ha^{-1} (PE). Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) recorded (19.13%) more panicle length over weedy check.

Filled grains panicle^{-1} was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest filled grains panicle^{-1} (82.9 panicle^{-1}) was found in weedy check which was significantly lower than the remaining treatments. The highest filled grains panicle^{-1} (115.8 panicle^{-1}) was found in weed free, which was significantly higher than other treatments. Among the herbicides, the highest filled grains panicle^{-1} (110.9 panicle^{-1}) was recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE), which was statistically at par with Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (110.2 panicle^{-1}), Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (109.8 panicle^{-1}), Oxidiargyl @ 100g a.i.ha^{-1} (PE) (105.5 panicle^{-1}) and Oxidiargyl @ 120g a.i.ha^{-1} (PE) (100.8 panicle^{-1}). Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) recorded (33.77%) more filled grains panicle^{-1} over weedy check.

Unfilled grains panicle^{-1} was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest unfilled grains panicle^{-1} (35.3) was found in weedy check. The highest unfilled grains panicle^{-1} (44.5 panicle^{-1}) was found in weed free. Among the herbicides, the highest unfilled grains panicle^{-1} (42.6 panicle^{-1}) was recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) which was at par with Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (41.7 panicle^{-1}) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (40.8 panicle^{-1}). Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) recorded (20.67%) more unfilled grains panicle^{-1} over weedy check.

1000-grains weight was affected non-significant by various treatments involving weed management practices. Among weed control treatments, the lowest 1000-grains weight (19.7 g) was found in weedy check. The highest 1000-grains weight (20.3 g) found in weed free. Among the herbicides, the highest 1000-grains weight (20.3 g) was recorded with the application of Ethoxy Sulfuron @30g a.i.ha^{-1} (PE). Ethoxy Sulfuron @30g a.i.ha^{-1} (PE) recorded (3.04%) higher 1000-grains weight over weedy check. Similar results have also been reported by Singh *et al.* (2013) and Prasuna *et al.* (2015) [19, 16]. Integrated weed management i.e, herbicides and hand weeding has been reported to be superior over application of herbicide alone by earlier workers as well (Rao *et al.*, 2015; Kumar *et al.*, 2018) [18, 6].

Crop Productivity

Grain yield was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest grain yield (21.3 q ha^{-1}) was found in weedy check. The highest grain yield (45.7 q ha^{-1}) was found in weed free.

Among the herbicides the significantly highest grain yield (43.4 q ha^{-1}) was recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE), which was statistically at par with Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (41.3 q ha^{-1}) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (40.1 q ha^{-1}). Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) recorded (103.75%) higher grain yield over weedy check.

Table 5: Effect of herbicides on grain, straw, biological yield (q ha^{-1}) and harvest index (%) of rice

	Treatments	Yield (q ha^{-1})			Harvest index (%)
		Grains	Straw	Biological	
T_1	Weedy check	21.3	33.8	55.1	38.6
T_2	Weed free	45.7	53.4	99.1	46.1
T_3	Bispyribac sodium @ 25g a.i ha^{-1} (PoE)	39.2	49.4	88.6	44.2
T_4	Penoxsulam @ 20 g a.i.ha^{-1} (PoE)	30.6	46.4	77.0	39.7
T_5	Penoxsulam @ 25 g a.i.ha^{-1} (PoE)	32.2	46.7	78.9	40.8
T_6	Penoxsulam @ 30 g a.i.ha^{-1} (PoE)	33.5	47.8	81.3	41.2
T_7	Oxidiargyl @ 80 g a.i.ha^{-1} (PE)	35.2	48.0	83.2	42.3
T_8	Oxidiargyl @ 100g a.i.ha^{-1} (PE)	37.2	49.1	86.3	43.1
T_9	Oxidiargyl @ 120g a.i.ha^{-1} (PE)	36.2	48.3	84.5	42.8
T_{10}	Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE)	40.1	50.1	90.2	44.4
T_{11}	Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE)	41.3	50.8	92.1	44.8
T_{12}	Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE)	43.4	52.0	95.4	45.5
	SEm (±)	1.3	1.7	3.1	1.5
	C.D. (P=0.05)	3.8	5.1	8.8	4.4

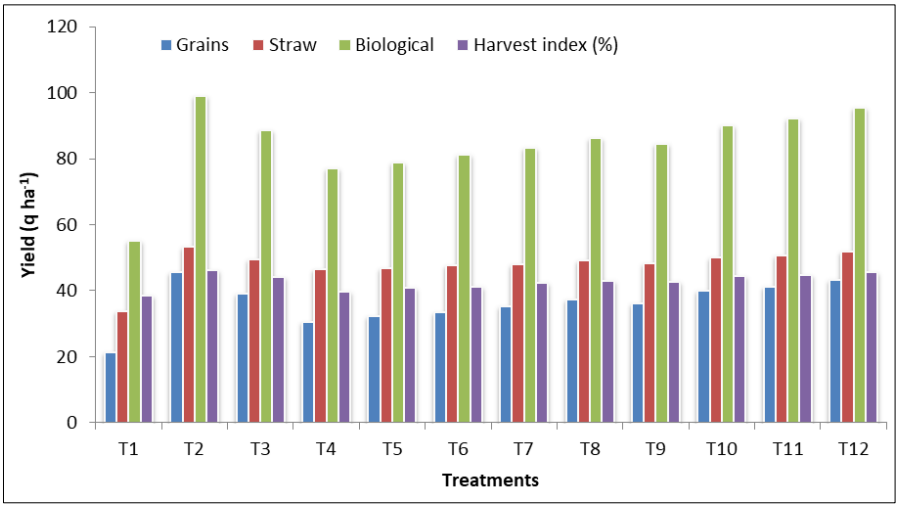

Fig 5: Effect of herbicides on grain, straw, biological yield (q ha^{-1}) and harvest index (%) of rice

Biological yield was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest biological yield (55.1 q ha^{-1}) found in weedy check. The highest biological yield (99.1 q ha^{-1}) was found in weed free. Similar findings were reported by Nayar *et al.* (2014) [10].

Among the herbicides, the highest biological yield (95.4 q ha^{-1}) was recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE), which was statistically at par with Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (92.1 q ha^{-1}) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (92.1 q ha^{-1}). Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) (73.13%) higher biological yield over weedy check.

Harvest index was significantly affected by various treatments involving weed management practices. Among weed control treatments, the lowest harvest index (38.6%) was found in weedy check while the highest harvest index (46.1%) in weed free. Among the herbicides the highest harvest index (45.5%) recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) followed by Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) than rest of the treatments. Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) recorded (17.87%) higher harvest index over weedy check. Similar findings were reported by Prakash *et al*. (2014) [14].

Economics

Cost of cultivation was affected by various treatments involving weed management practices. Among weed control treatments, the lowest cost of cultivation (Rs. 40600 ha^{-1}) found in weedy check, which was lower than the remaining treatments. The highest cost of cultivation (Rs. 47200 ha^{-1}) was found in weed free treatment, which was higher than other treatments. Among the herbicides, the highest cost of cultivation (Rs. 41830 ha^{-1}) was recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE), followed by Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (Rs. 41740 ha^{-1}) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (Rs. 41730 ha^{-1}). Nagarjuna *et al.* (2015) and Parameswari and Srinivas (2017) [9, 12] also reported similar results.

Table 6: Effect of various treatments on economic analysis of rice cultivation

Treatment		Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C ratio
T_1	Weedy check	40600	50916	10316	1.25
T_2	Weed free	47200	106948	59890	2.27
T_3	Bispyribac sodium @ 25g a.i ha^{-1} (PoE)	41570	92168	50598	2.22
T_4	Penoxsulam @ 20 g a.i.ha^{-1} (PoE)	41200	72888	31688	1.77
T_5	Penoxsulam @ 25 g a.i.ha^{-1} (PoE)	41240	76444	35204	1.85
T_6	Penoxsulam @ 30 g a.i.ha^{-1} (PoE)	41280	79436	38166	1.92
T_7	Oxidiargyl @ 80 g a.i.ha^{-1} (PE)	41470	83200	41730	2.01
T_8	Oxidiargyl @ 100g a.i.ha^{-1} (PE)	41560	87732	46212	2.11
T_9	Oxidiargyl @ 120g a.i.ha^{-1} (PE)	41650	85436	43826	2.05
T_{10}	Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE)	41730	94232	52502	2.26
T_{11}	Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE)	41790	96956	55216	2.32
T_{12}	Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE)	41850	101720	59752	2.43
	SEm (±)	-	1139	971	0.01
	C.D. (P=0.05)	-	3425	2915	0.04

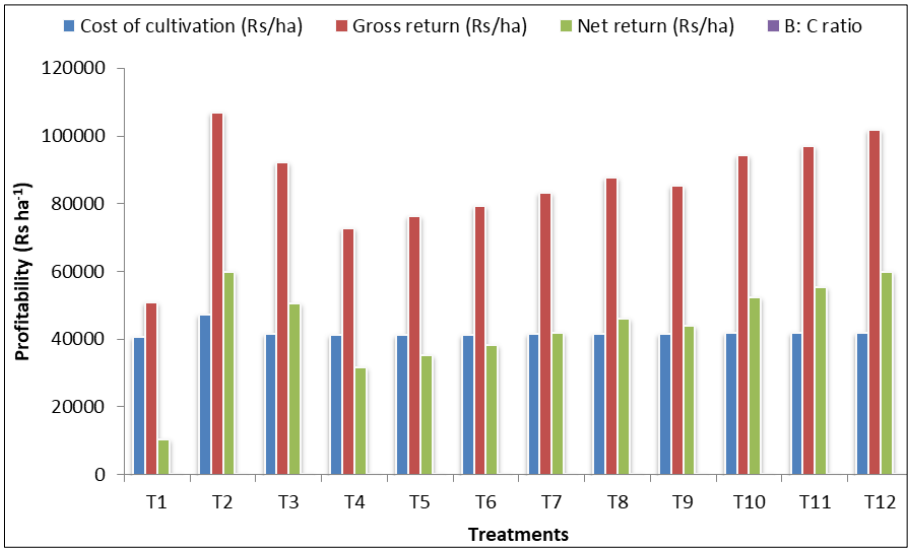

Fig 6: Effect of various treatments on economic analysis of rice cultivation

Gross return was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest gross return (₹50916 ha^{-1}) was found in weedy check, which was significantly lower than the remaining treatments. The highest gross return (₹106948 ha^{-1}) was found in weed free treatment, which was higher than other treatments. Among the herbicidal treatments, the highest gross return (₹ 101720 ha^{-1}) was recorded with the application of Ethoxy Sulfuron @30g a.i.ha^{-1} (PE) followed by Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (₹ 96956) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (₹ 94232 ha^{-1}). Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) was recorded (99.78%) higher gross return over weedy check.

Net return was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest net return (₹ 10316 ha^{-1}) was found in weedy check and significantly lower than the remaining treatments, while the highest net return (₹ 59890 ha^{-1}) was found in weed free treatment and significantly higher than other treatments. Among the herbicides, the highest net return (₹ 59752 ha^{-1}) was recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) followed by Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (₹ 55216 ha^{-1}) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (₹ 52502 ha^{-1}). Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) recorded (479.21%) higher net return over weedy check. These findings are in close agreement with the results of Pradhan *et al*. (2010) Longkumer *et al*. (2013) and Kumar *et al*. (2015) [13, 8, 7].

B: C ratio was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest B: C ratio (1.25) was found in weedy check, which was significantly lower than the remaining treatments while the highest B: C ratio (2.27) was recorded in weed free treatment. Among the herbicides, the highest B: C ratio was recorded with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) (2.43) followed by Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) (2.32) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE) (2.26). Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) was recorded (94.4%) higher B: C ratio over weedy check. Kumar *et al*. (2015) and Nivetha *et al*. (2017) [7, 11] also reported similar results.

Conclusion

Based on the results of experimentation, it can be concluded that all weed control practices proved effective in controlling the weeds in rice and gave significantly higher grain yield over weedy check. Among the different treatments, manual weeding to keep the plot weed free is the most effective weed control measure to control narrow, broad leaved and sedge weeds and resulted into higher value of weed control efficiency followed by Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE), Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) and Ethoxy Sulfuron @

20g a.i.ha^{-1} (PE). Highest growth parameters, yield attributes yield of rice and nutrient uptake was noticed with weed free, which was found statistically at par with the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) and Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE). Among weed management treatments Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) was found excellent in gross return, net return, and B: C ratio followed by Ethoxy Sulfuron @ 25g a.i.ha^{-1} (PE) and Ethoxy Sulfuron @ 20g a.i.ha^{-1} (PE). Although maximum net return was obtained in weed free followed by Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) but non-availability of human power may be a constraint therefore chemical weed management practice will be better option. Thus the application of Ethoxy Sulfuron @ 30g a.i.ha^{-1} (PE) seems better for higher productivity and profitability of rice crop**.**

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