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Influence of herbicide-based weed management on nutrient uptake, grain quality, yield and economics in Transplanted Rice (*Oryza sativa* L.)

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Abstract

A study was carried out in SKUAST-Jammu during *kharif* seasons of 2023 and 2024 to analyse the effect of variable dose of herbicides and their combinations on quality parameters, nutrient uptake, soil properties, relative economics, growth and yield parameters in transplanted rice (*Oryza sativa* L.). The treatments consist of 100% and 75% dose of pre and post emergence herbicides. Among different treatments, the higher protein content (7.98%), amylose content (22.80%), number of tillers (248.33 no./m²), grain yield (2.96 t/ha), straw yield (5.57 t/ha) and benefit-cost ratio (1.97) was recorded by application of pre-emergence application (PE) of pyrazosulfuron-ethyl 15 g/ha followed by (*fb*) post-emergence application (PoE) of triafamone + ethoxysulfuron 66.5 g/ha which was statistically equivalent to pyrazosulfuron-ethyl 15 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE. The similar treatments have also recorded the higher nutrient uptake by crop, lowest nutrient uptake by weeds and the lowest available nutrient present in soil at harvest stage of crop. Henceforth, it was concluded that the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha and PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE bispyribac-sodium 25 g/ha shows the highest protein content, number of tillers, grain yield, nutrient uptake by crop and benefit-cost ratio.

Keywords: Herbicide, growth, nutrient uptake, protein content, transplanted rice

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crop in the world. At global level, it is the staple food for more than half of the world's population. It plays a vital role in ensuring food security and supporting rural livelihoods, especially in developing countries. India is the largest producer of rice in the world after China and the *kharif* rice is the main contributor in achieving this position. India produces 26 per cent of the world's rice, making it one of the largest producers in the world (FAO, 2024) [4]. However, the transplantation method of rice cultivation is commonly used by farmers because it gives better crop establishment and higher yield. In this method, the weed infestation is a serious problem particularly during the early growth stages of crop. The weeds were compete with rice plants for nutrients, water, light and space which reduces crop growth, yield, and grain quality (Rao *et al.*, 2007) [9]. To control this problem effectively, the different weed control methods were used which are time consuming, labour intensive and costly. Among different methods, the chemical weed control through herbicides is the most effective (Chauhan, 2012) [3]. In this method, the lower dose of herbicides may result in poor weed control, leading to higher weed competition, reduced nutrient uptake and crop growth whereas the higher dose can improve weed control but may cause crop injury, negatively affect soil health and nutrient uptake. The application of correct dose of herbicides and their combinations helps in controlling a wide range of weeds which help in improving the soil properties, nutrient uptake, productivity and quality of rice crop (Singh *et al.*, 2015) [12]. Therefore, studying the effect of different herbicide doses and combinations on soil properties, nutrient uptake, yield, grain quality and economics is important for achieving higher productivity and maintaining soil health in transplanted rice.

2. Materials and Methods

The study was conducted at Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main campus Chatha (Jammu) (320 - 40' N, 740 -58' E; with 332 m above mean sea level) during the *Kharif* seasons of 2023 and 2024. The textural class of the soil was sandy clay loam with pH 7.5, low organic carbon (4.34 g/kg), low available nitrogen (236.62 kg/ha), medium available phosphorus (14.35 kg/ha) and medium potassium (163.74 kg/ha). The gross size of the plot was 28 m² (4m x 7m) and net size was 19.2 m² (3.2m x 6m). The rice variety ‘Basmati-370’ was transplanted at spacing of 20 × 10 cm. The pre-emergence (PE) herbicide was applied at 2 days after transplanting (DAT) and post-emergence (PoE) herbicide was applied at 25 days after transplanting (DAT). The recommended dose of fertilization (RDF) by crop is 30-20-10 kg N-P-K/ha. The experiment was laid in Randomized Block Design (RBD) with three replications and consists of nine treatments (Table 1).

Table 1: Treatment details of the experimental study

S. No.	Treatments
T ₁	PE Pyrazosulfuron-ethyl 15 g/ha
T ₂	PE Pyrazosulfuron-ethyl 11.25 g/ha
T ₃	PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 66.5 g/ha
T ₄	PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 49.87g/ha
T ₅	PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE bispyribac-sodium 25 g/ha
T ₆	PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE bispyribac-sodium 18.75 g/ha
T ₇	PoE Bispyribac-sodium 25 g/ha (Farmer’s Practice)
T ₈	Weed free
T ₉	Unweeded check

The chemical analysis of plant and weed samples were analysed by taking their sample at harvesting stage to measure the absorption of nitrogen, phosphorus and potassium. In this the nutrient uptake by samples were calculated by multiplying them with the percentage content of nutrient acquired by them with their dry biomass by using the formula given below:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient uptake (\%)} \times \text{Dry matter accumulation (kg/ha)}}{100}$$

The protein content was determined by estimating the nitrogen in the crop sample using the Kjeldahl method. The grain samples were dried, ground and analyzed in which the nitrogen percentage obtained was multiplied by a factor of 5.95 to calculate protein content. This parameter reflects the nutritional quality of rice (AOAC, 1970) [1]. However, the amylose content was estimated usinf the iodine colorimetric method. The ground rice samples were treated with chemicals and iodine solution, producing blue colour which was measured by using a spectrophotometer. This parameter is important for evaluating cooking and eating quality of rice grains (Juilano, 1971). The observation consist of the parameters related to soil properties, nutrient uptake, grain quality, relative economics, growth and yield parameters. The soil samples were collected after the harvest of crop to analyze the soil pH, electrical conductivity, nitrogen, phosphorus and potassium which help in assessing the impact of different treatments on soil fertility

status. The nutrient uptake was determined by estimating their uptake of nitrogen, phosphorus and potassium by grain and straw by crop and total uptake of nutrients by weed biomass. The grain quality parameters such as such as grain length, grain breadth, length/breadth ratio, 1000-grain weight, hulling%, milling%, protein content, amylose conent and kernel length after cooking were recorded to evaluate the effects of treatments on rice quality. The growth and yield parameters consists of plant height, number of tillers, dry matter accumulation, number of panicles, grain yield, straw yield and harvest index. The relative economics consists of cost of cultivation, gross returns, net returns and benefit-cost ratio. In addition to these, the some quality parameters with their given formulas as listed below: Grain length (mm)

$$\text{Length/Breadth ratio} = \frac{\text{Grain length (mm)}}{\text{Breadth length (mm)}}$$

$$\text{Hulling (\%)} = \frac{\text{Weight of brown rice}}{\text{Weight of paddy}} \times 100$$

$$\text{Milling (\%)} = \frac{\text{Weight of milled rice}}{\text{Weight of paddy}} \times 100$$

Statistical analysis: The data obtained for two consecutive years were pooled and analyzed for check the uniformity of error variance. The statistical analysis was carried out using analysis of variance (ANOVA) under a randomized block design to assess the effects of different treatments. The significance of difference among treatment means was tested at 5% probability level and critical difference values were used for comparing the mean value (Gomez And Gomez, 1984) [5].

3. Results and Discussion

Quality parameters

The results revealed that the different crop quality parameters were failed to show any significant effect by the different dose of herbicides. As shown in fig.1 and fig.2, the highest protein content, amylose content, grain length (7.05, 7.02 mm), length/breadth ratio (4.12, 4.06), 1000 grain weight, hulling (79.76, 79.33%), milling (78.70, 78.61%), Kernel length after cooking (12.87, 12.81 mm) and lower grain breadth (1.71, 1.73 mm) was recorded by the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha and PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE bispyribac-sodium 25 g/ha (Table 2). The similar results were observed in the uptake of amylose and protein content by the crop (Fig.1&2). The grain quality of the crop was improved by the application of herbicides due to better weed suppression and reduce crop-weed competition which helps in improving the quality of the grain.

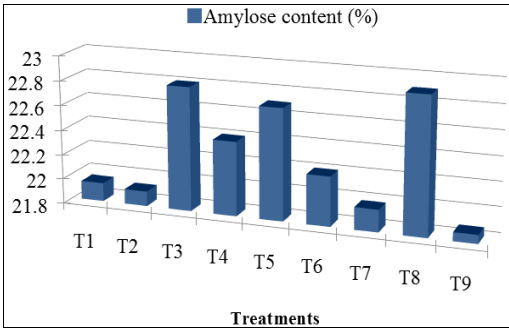


Fig 1: Effect of different dose of herbicides on amylose content in transplanted rice (pooled values for two years)

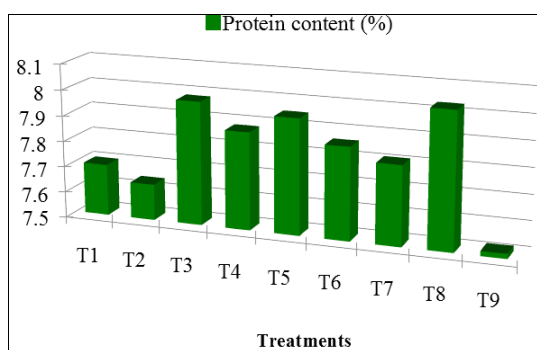


Fig 2: Effect of different dose of herbicides on protein content in transplanted rice (pooled values for two years)

Growth parameters

The results described that the effect of the treatments were remain significant at 60 DAT and at harvest. At 60 DAT the higher plant height, number of tillers and dry matter accumulation exhibited by the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha and PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE bispyribac-sodium 25 g/ha. The similar trend was also observed at harvest stage of crop (Fig.3&4). This was mainly due to the reduced crop-weed competition by which there was decrease weed counts and weed dry matter by which help in better uptake of light, nutrients and water which ultimately improve the growth of crop (Choudhary and Dixit, 2024) [2].

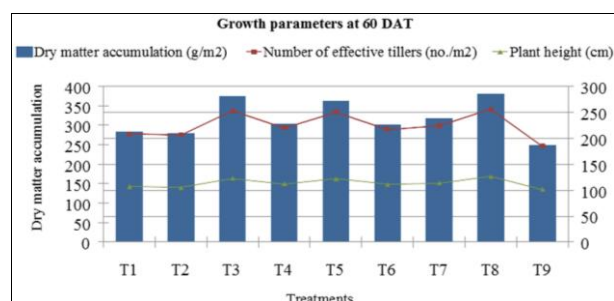


Fig 3: Effect of different dose of herbicides on growth parameters at 60 DAT in transplanted rice (pooled values for two years)

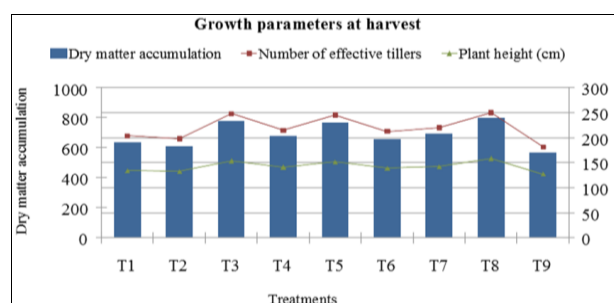


Fig 4: Effect of different dose of herbicides on growth parameters at harvest in transplanted rice (pooled values for two years)

Yield attributes and Yield

The results shown that the yield attributes and yield of the crop were significantly affected by these herbicidal treatments. In this experiment, the highest number of tillers (248.33 no./m²), number of grains per panicle (73.00), Grain yield (2.96 t/ha) and Straw yield (5.57 t/ha) was recorded by the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha which was statistically at par with PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE bispyribac-sodium 25 g/ha (Table 3). This was mainly achieved by the effective weed

suppression with herbicidal treatments which leads to better sunlight, water and nutrient uptake by the crop (Prasath and Ramesh, 2015) [7].

Nutrient uptake by crop

The results revealed that the nutrient uptake by crop was significantly affected by the different dose of herbicides. Among different treatments, the highest nitrogen uptake by grain and straw (39.68, 27.09 kg/ha), phosphorus (8.61, 8.08 kg/ha) and potassium (19.38, 55.12 kg/ha) was recorded by the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha which was statistically at par with PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE bispyribac-sodium 25 g/ha (Table 4). The nutrient uptake of crop is increased by the application of herbicides due to effective weed control and reduce competition for soil nutrients. The better availability of nutrients in herbicide treated plots lead to higher nutrient uptake by grain and straw of crop which help in increasing their growth and productivity (Singh *et al.*, 2013) [11].

Nutrient uptake by weeds

The recorded data revealed that the nutrient uptake by weeds was significantly affected by the different dose of herbicides. Among all the treatments, the lowest nitrogen (4.30 kg/ha), phosphorus (2.27 kg/ha) and potassium uptake (5.51 kg/ha) by weeds was recorded by the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha which was statistically at par with PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE bispyribac-sodium 25 g/ha (Table 5). The lowest nutrient uptake of weeds by the application of herbicides is mainly due to the effective weed control which reduce their population and dry matter. As lower weed population takes less nutrients compared to uncontrolled weed growth, leaving more nutrients available to the crop plants (Rana and Angiras, 1999) [8].

Soil parameters

The observed result revealed that the the soil properties were failed to show any significant effect by the different dose of herbicides. However, the lowest nitrogen (228.18 kg/ha), phosphorus (14.66 kg/ha), potassium (157.56 kg/ha) and highest organic matter (4.56 g/kg) was recorded by the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha (Table 6). The lowest available nutrients and higher organic carbon was present in soil by herbicidal application was mainly due to effective weed control which reduces the weed population, addition of weed residue in soil and increases nutrient uptake by crop. This results in more addition of residue retention and reduces the available nutrients in the soil.

Relative economics

The first stage of adopting any technology, method and suggestion is mostly determined by its input cost and profit. In this aspect, the net returns and benefit-cost ratio were the main parameters in economic viability. Among different treatments, the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha with net returns (101750 ₹/ha), benefit-cost ratio (1.97) (Table 7). This was due to the higher better weed control which leads to higher production of grain and straw yield. This leads to fetch good net profit and ultimately receive a higher benefit-cost ratio (Singh *et al.*, 2021) [10].

Table 2: Effect of different dose of herbicide on quality parameters in transplanted rice (pooled values for two years)

Treatment	Grain length (mm)	Grain breadth (mm)	L/B ratio	1000-grain weight (g)	Milling percentage (%)	Hulling percentage (%)	Kernel length after cooking (mm)
PE Pyrazosulfuron-ethyl 15 g/ha	6.86	1.82	3.77	20.72	76.89	77.45	12.25
PE Pyrazosulfuron-ethyl 11.25 g/ha	6.81	1.84	3.70	20.66	76.22	76.78	11.87
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 66.5 g/ha	7.05	1.71	4.12	20.97	78.70	79.76	12.87
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 49.87g/ha	6.98	1.76	3.97	20.85	78.20	78.73	12.70
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE bispyribac-sodium 25 g/ha	7.02	1.73	4.06	20.94	78.61	79.33	12.81
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE bispyribac-sodium 18.75 g/ha	6.96	1.78	3.91	20.81	78.11	78.42	12.62
PoE Bispyribac-sodium 25 g/ha (Farmer's Practice)	6.91	1.80	3.84	20.78	77.75	77.66	12.46
Weed free	7.09	1.67	4.25	21.08	79.35	80.27	12.93
Unweeded check	6.72	1.87	3.59	20.47	74.34	74.56	11.56
SEM±	0.05	0.03	0.07	0.76	0.63	0.57	0.18
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 3: Effect of different dose of herbicide on yield attributes and yield in transplanted rice (pooled values for two years)

Treatment	Effective tillers (no. /m ²)	Panicles/m ²	Grains per panicle	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
PE Pyrazosulfuron-ethyl 15 g/ha	203.66	200.67	64.00	2.42	4.30	36.05
PE Pyrazosulfuron-ethyl 11.25 g/ha	198.00	198.00	61.67	2.34	4.13	36.13
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 66.5 g/ha	248.33	246.00	73.00	2.96	5.57	34.70
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 49.87g/ha	215.00	213.67	65.00	2.53	4.65	35.26
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE bispyribac-sodium 25 g/ha	245.33	243.67	71.67	2.88	5.38	34.89
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE bispyribac-sodium 18.75 g/ha	212.67	209.33	64.67	2.54	4.64	35.38
PoE Bispyribac-sodium 25 g/ha (Farmer's Practice)	220.33	216.67	65.33	2.57	4.88	34.52
Weed free	250.33	246.34	74.00	3.10	5.71	35.21
Unweeded check	181.67	179.67	59.67	2.12	3.83	35.61
SEM±	7.25	8.25	2.06	0.10	0.16	1.28
CD (P=0.05)	21.75	24.71	6.13	0.30	0.50	NS

Table 4: Effect of different dose of herbicide on nutrient uptake by grain and straw in transplanted rice (pooled values for two years)

Treatment	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Potassium (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
PE Pyrazosulfuron-ethyl 15 g/ha	29.17	14.29	43.46	4.94	3.54	8.48	12.12	36.33	48.45
PE Pyrazosulfuron-ethyl 11.25 g/ha	27.66	13.33	40.99	4.54	3.20	7.74	11.22	34.10	45.32
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 66.5 g/ha	39.68	27.09	66.77	8.61	8.08	16.69	19.38	55.12	74.50
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 49.87g/ha	31.72	18.46	50.18	6.04	4.53	10.57	14.14	42.89	57.03
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE bispyribac-sodium 25 g/ha	38.33	26.02	64.35	8.12	7.67	15.79	18.38	54.05	72.43
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE bispyribac-sodium 18.75 g/ha	31.10	16.94	48.04	5.82	3.92	9.74	13.47	40.11	53.58
PoE Bispyribac-sodium 25 g/ha (Farmer's Practice)	32.76	20.26	53.02	6.30	5.27	11.57	15.20	45.75	60.95
Weed free	42.13	28.46	70.59	9.26	8.98	18.24	19.74	56.91	76.65
Unweeded check	24.14	11.16	35.30	3.74	2.69	6.43	9.17	31.33	40.50
SEM±	1.56	1.14	2.17	0.61	0.57	0.82	0.83	1.77	1.61
CD (P=0.05)	4.67	3.41	6.52	1.82	1.72	2.45	2.47	5.31	4.82

Table 5: Effect of different dose of herbicide on nutrient uptake by weeds in transplanted rice (pooled values for two years)

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
PE Pyrazosulfuron-ethyl 15 g/ha	15.81	7.44	25.18
PE Pyrazosulfuron-ethyl 11.25 g/ha	20.31	9.55	33.55
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 66.5 g/ha	4.30	2.27	5.51
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 49.87g/ha	9.09	4.26	12.84
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE bispyribac-sodium 25 g/ha	4.93	2.54	6.52
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE bispyribac-sodium 18.75 g/ha	9.62	4.47	13.83
PoE Bispyribac-sodium 25 g/ha (Farmer's Practice)	8.27	3.89	11.31
Weed free	-	-	-
Unweeded check	23.50	11.33	41.55
SEM±	0.31	0.17	0.35
CD (P=0.05)	0.93	0.50	1.05

Table 6: Effect of different dose of herbicide on soil properties at harvest in transplanted rice (pooled values for two years)

Treatment	pH	EC (dS/m)	OC (g/kg)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
PE Pyrazosulfuron-ethyl 15 g/ha	7.51	0.28	4.51	231.01	14.75	160.52
PE Pyrazosulfuron-ethyl 11.25 g/ha	7.45	0.25	4.49	231.34	14.76	161.00
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 66.5 g/ha	7.52	0.28	4.56	228.18	14.66	157.56
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE triafamone + ethoxysulfuron 49.87g/ha	7.54	0.27	4.53	230.16	14.76	159.19
PE Pyrazosulfuron-ethyl 15 g/ha <i>fb</i> PoE bispyribac-sodium 25 g/ha	7.52	0.28	4.55	228.85	14.73	158.02
PE Pyrazosulfuron-ethyl 11.25 g/ha <i>fb</i> PoE bispyribac-sodium 18.75 g/ha	7.54	0.28	4.52	230.41	14.74	159.67
PoE Bispyribac-sodium 25 g/ha (Farmer's Practice)	7.51	0.27	4.48	229.34	14.75	158.81
Weed free	7.52	0.29	4.58	228.01	14.54	157.06
Unweeded check	7.51	0.28	4.47	233.01	14.85	162.26
SEm±	0.34	0.01	0.22	4.72	0.42	5.67
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 7: Effect of different dose of herbicide on relative economics in transplanted rice (pooled values for two years)

Treatments	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Pyrazosulfuron ethyl @ 15 g/ha (RDH) at 2-3 DAT	50432	125123	74691	1.48
Pyrazosulfuron ethyl @ 11.25 g/ha (75% RDH) at 2-3 DAT	49375	120557	71182	1.44
Pyrazosulfuron ethyl @ 15 g/ha (RDH) at 2-3 DAT <i>fb</i> Triafamone + Ethoxysulfuron @ 66.5 g/ha (RDH) at 25-30 DAT	51618	153368	101750	1.97
Pyrazosulfuron ethyl @ 11.25 g/ha (75% RDH) at 2-3 DAT <i>fb</i> Triafamone + Ethoxysulfuron @ 49.87g/ha (75% RDH) at 25-30 DAT	51250	130859	79609	1.55
Pyrazosulfuron ethyl @ 15 g/ha (RDH) at 2-3 DAT <i>fb</i> Bispyribac-Na @ 25 g/ha (RDH) at 25-30 DAT	51458	149134	97676	1.90
Pyrazosulfuron ethyl @ 11.25 g/ha (75% RDH) at 2-3 DAT <i>fb</i> Bispyribac-Na @ 18.75 g/ha (75% RDH) at 25-30 DAT	51016	131327	80311	1.57
Bispyribac-Na @ 25 g/ha (RDH) at 25-30 DAT	49933	133239	83306	1.67
Weed free	65877	160415	94538	1.44
Weedy check	48227	109534	61307	1.27

Conclusion

Based on the two year study, it was concluded that the application of PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE triafamone + ethoxysulfuron 66.5 g/ha and PE Pyrazosulfuron-ethyl 15 g/ha *fb* PoE bispyribac-sodium 25 g/ha has shown the highest milling percentage, dry matter accumulation, grain yield, nutrient uptake by crop, soil organic matter and benefit-cost ratio.

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