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Assessment of post-emergence herbicide mixes on weed control and weed control efficiency, weed index and yield in direct seeded rice (*Oryza sativa* L.)

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Abstract
Direct-seeded rice (DSR) has emerged as a popular alternative to traditional transplanting due to its cost-efficiency and labor-saving benefits. However, weeds significantly threaten DSR productivity. The experiment was laid out in Randomized Block Design with three replications to find out the suitable weed management practices on growth and yield of rice crop, to assess the losses in yield of rice caused due to weeds, and economics of different treatments. Field trial was laid out in RBD with three replications, Ten treatments *viz.* T_1: Chlorimuron Ethyl 25% WP @ 37.05 g a.i./ha (PoE), T_2: Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 52.50 g a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE) T_3: Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE), T_4: Bispyribac sodium 10% SC @ 25 ml a.i./ha (PoE), T_5: Pyrazosulfuron 10% WP@ 215g a.i./ha (PoE), T_6: Triafamone 20% + ethoxysulfuron10% WG @ 66.5 g a.i./ha (PoE), T_7: Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 135 ml a.i./ha (PoE), T_8: Fenoxoprop (PE) fb Halosulfuron @ (56 fb 67) ml a.i./ha (PoE), T_9: Hand weeding (20 and 40 DAS) and T_{10}: untreated control,. Among the herbicides tested, T_3: Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE), and being at par with T_2: Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 52.50 g a.i./ ha+ Spreadmaxa@ 0.5 ml litre-1(PoE), showed superior weed control, better growth parameters, and increased yields. Additionally, T_7: Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 135 ml a.i./ha (PoE), (T_7) effectively controlled *Paspalum Monspeliensis*. The study highlights the need to tailor weed control methods to local conditions, selecting appropriate herbicides and practices based on the prevalent weed species in the farming system. Understanding the specific effects of post-emergence herbicides is vital for effective weed management in direct-seeded rice.

Keywords: DSR, herbicide, RBD etc.

Introduction
Rice is the most widely cultivated cereal crop and the main source of nutrition for over half of the global population. Globally, rice production amounts to 506.23 million tonnes from 163.26 million hectares of land, with a productivity rate of 3.10 tonnes per hectare (USDA, 2022-23). Asia is responsible for about 90% of the world's rice production and consumption (FAO, 2014) [3], and rice provides two-thirds of the daily calorie intake for Asian people (Anonymous, 2017) [1]. In modern agriculture, rice is crucial for global food security, serving as a staple for over 50% of the world's population and providing more than 20% of their calorie intake (Fukagawa *et al.*, 2019) [4]. Rice belongs to the Poaceae family, one of the most diverse angiosperm families globally (Ghahremaninejad *et al.*, 2021) [6]. As India's population grows and dietary preferences shift, the demand for rice is expected to increase. However, with decreasing acreage for rice cultivation, higher yields must drive the rise in rice production. Therefore, enhancing the sustainability of rice ecosystems while increasing production and reducing water and labor use is essential. Direct-seeded rice (DSR), a cost-effective and labor-saving alternative to traditional transplanting, has gained popularity. Unlike conventional methods, where seedlings are grown in nurseries and then transplanted into flooded fields, DSR involves sowing seeds directly into prepared fields.

This approach offers advantages such as resource conservation, labor efficiency, and adaptability to various agroecosystems (Kachroo *et al*., 2011) [8]. It also facilitates the early establishment of wheat crops (Kachroo *et al*., 2011) [8]. Changes in agricultural practices influence weed prevalence and distribution (Ghahremaninejad *et al*., 2012) [7]. Weeds pose a significant threat to DSR crops (K Rao *et al*., 2007) [17] by competing for sunlight, water, and nutrients. High weed infestation in the early stages of DSR can result in up to 90% yield loss. Thus, weeds are the primary biological constraint in DSR production, highlighting the need for effective weed management strategies to ensure DSR's success and productivity (Chauhan *et al*., 2011) [2]. Direct-seeded rice (DSR) has gained popularity in recent years as an alternative to traditional transplanting methods. Instead of puddling fields and transplanting seedlings from nurseries, DSR involves directly sowing seeds in the field. This method eliminates the need for nursery raising, puddling, and transplanting, saving about 25% (250-300 man-hours) of labor, reducing cultivation costs, and generating additional income. DSR also conserves 35-57% of irrigation water, allows for earlier crop maturity, and facilitates early Rabi crop sowing Kumar *et al*. (2021) [12] and Pal *et al*. (2023) [15]. It supports conservation agriculture by reducing tillage and methane emissions, making it suitable amid declining water tables, rising fuel and electricity costs, and climate change Pal *et al*. (2024) [14]. However, weeds pose a significant challenge in DSR because both crop seedlings and weeds emerge simultaneously, leading to intense competition for resources. The absence of standing water in DSR fields exacerbates weed infestation. The critical period for crop-weed competition ranges from 20 to 50 days after sowing, and poor weed management can lead to 50-90% yield losses. Effective weed management is crucial for the success of DSR. Due to labor shortages and high wages, chemical weed control is often preferred for its speed and cost-effectiveness. Managing diverse weed flora in DSR can be achieved by sequentially applying pre-emergence and post-emergence herbicides. This study evaluated the effectiveness of various herbicides and their sequences on weed dynamics and economics in direct-seeded rice. Herbicidal weed management is the most efficient method for controlling diverse weed populations in DSR. Strategically combining herbicides is necessary to address the complex weed composition. Post-emergence herbicides are crucial in modern weed management, allowing for selective and timely intervention to control weed infestations while maintaining the health and vigor of DSR plants. Understanding the specific impacts of post-emergence herbicides is vital for effective weed management in DSR (Saikia *et al*., 2024 and Kumar *et al*. 2021) [18, 12].

Materials and Methods

A Field trial was laid out during the kharif season (2021-22) in RBD with three replications, Ten treatments *viz.* T_1: Chlorimuron Ethyl 25% WP @ 37.05 g a.i./ha (PoE), T_2: Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 52.50 g a.i./ ha+ Spreadmaxa@ 0.5 ml litre-1(PoE) T_3: Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE), T_4: Bispyribac sodium 10% SC @ 25 ml a.i./ha (PoE), T_5: Pyrazosulfuron 10% WP@ 215g a.i./ha (PoE), T_6: Triafamone 20% + ethoxysulfuron10% WG @ 66.5 g a.i./ha (PoE), T_7: Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 135 ml a.i./ha (PoE), T_8: Fenoxoprop (PE) fb Halosulfuron @ (56 fb 67) ml a.i./ha (PoE), T_9: Hand weeding (20 and 40 DAS) and T_{10}: untreated control,. The herbicide treatments were applied at 1 DAS and 20 DAS as Pre and Post emergence to weeds, respectively. The crop was direct seeded on 25 July, 2022 of rice variety NDR-2064. A recommended dose of nutrients of N, P, K and Zn at 120:60:40:25 kg/ha, respectively were applied in the crop. Fertilizers were applied using urea, diammonium phosphate, and muriate of potash. Herbicides were sprayed 14 days after sowing with a knapsack sprayer for post-emergence weed control. To measure rice plant biomass, plants from a running meter of length were uprooted and oven-dried. Weed density and biomass were assessed by randomly placing a $1m^{-2}$ cm quadrat at two locations in each plot. Grain yield was measured at 14% moisture content. Statistical analysis was performed using the Analysis of Variance method as described by Gomez and Gomez.

Results and Discussion

The density of the weed species and total weeds at all plant growth were affected significantly due to different weed control practices (Table-1 and Fig.-1).

Among all weed management practices hand weeded plot was found zero weed density while among herbicide Sequential spray of Fenoxoprop (PE) fb Halosulfuron @ (56 fb 67) ml a.i./ha (PoE) recorded significantly lower density of at 30 DAS and 60 DAS over rest of the herbicidal treatments. While Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE) was recorded lower weed density at 60, and 90 and at harvest stage fallowed by Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 52.50 g a.i./ ha+ Spreadmaxa@ 0.5 ml litre-1(PoE) and Triafamone 20% + ethoxysulfuron10% WG @ 66.5 g a.i./ha (PoE) However lowest and highest weed density was recorded with Hand weeding (20 and 40 DAS) and Untreated (Control) treatments, similar trend is also find by Walia *et al*., (2012) [23]; Kumar and Singh, (2016) [13]; Saphi *et al*., (2018) [19].

Data presented in Table-.1 and fig 2 indicate that highest weed control efficiency at 60 DAS was recorded with treatment T_3: Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g a.i./ ha+ Spreadmaxa @ 0.5 ml. litre-1(PoE) (89.26%). followed by T_2: Bispyribac sodium 20% + p.yrazosulfuron 15% WDG @ 52.50 g a.i./ ha+ Spreadmaxa@ 0.5 ml litre-1(PoE) (77.74%), Fenoxopro.p (PE) fb Halosulfuron @ (56 fb 67) ml a.i./ha (PoE) (75.93%) and Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 135 ml a.i./ha (PoE) (74.44%).

Similar trend was observed as it was at 60 days stage with respect of weed management pract.ices at 90 DAS, and at harvest. The highest weed con.trol efficiency was recorded with T_3: (85.82%), T_2: (80.60%) and at harvest T_3: (87.51%), T_2: (81.49%) was very much comparable with Hand weeding (20 and 40 DAS) treatment (100%) at 30 DAS, 60 DAS and (94.28%), at harvest (94.40%). This was because of efficient control of weeds under this treatment resulted in lower dry matter of weeds. Similar results was reported by. Kaur *et al.* (2015) [9], Yadav *et al.* (2014) [24].

An examination of data presented in table-2 and fig 3 clearly indicates that various weed management practices affected the grain, straw and total biological yield significantly.

Crop kept Hand weeding (20 and 40 DAS) upto 60 DAS (T_9) being at par with T_3, and T_2 but produced significantly the highest grain (60.10 q ha^{-1}), straw (80.96 q ha^{-1}) and total biological yield (141.06 q ha^{-1}) as compare to rest of treatments. Among the herbicides treatments, application of Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE) being at par with T_2, T_7 and T_6 but produced significantly higher grain, straw, yield and total biological yield over rest of the treatments. Untreated (Control) produce significantly the lowest grain (39.20 q ha^{-1}), straw (58.06 q ha^{-1}) and total biological yield (97.25 q ha^{-1}) as compare to rest of the treatments.

Data under table-4.13 further revealed that various weed management treatment did not affected the harvest index statistically. However, Hand weeding (20 and 40 DAS) upto 60 DAS recorded the highest value of harvest index (42.62%) followed by T_3, T_2, T_6, T_7, T_5 and T_1 respectively. The lowest harvest index (40.30%) was recorded with Untreated (Control). Similar trend is find Sharma *et al*., (2014) [20]; Gaire *et al*., (2019) [5] Saikia *et al*., 2024 and Kumar *et al*. 2021 [18, 12].

Grain yield of crop depends upon the availability of nutrients to crop plant, which significantly affected the yield attributes. The efficient method of weed control enhance the growth and development (yield attributes) of crop due to lower crop-weed competition and higher availability of nutrients to crop. Under the present study Hand weeding (20 and 40 DAS) upto 60 days resulted in lower weed density and weed dry weight and higher availability of nutrient to crop which improved growth and yield attributes and finally the higher yield (grain and straw) was recorded

Among the herbicide treatments, spray of Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g. a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE) T_3, controlled the both type of weeds (narrow and broad leaves) resulted in higher availability of nutrient to crop growth and yield attributes as compared to Untreated (Control) which had highest crop-weed competition resulted in poor growth and yield attributes and finally the lower grain and straw yield. the result was in conformity with Walia *et al*., (2012) [23]; Kumar and Singh, (2016) [13]; Gaire *et al*., (2019) [5].

Table 1: Weeds Density (No./m^2), Weed control efficiency % and Weed index % as affected by various Weed management practices at different growth stages of crop growth in direct seeded rice.

	Treatment	Density of weeds (No./m2)				Weed control efficiency %	Weed index %
		30 DAS	60 DAS	90 DAS	At harvesting	60 DAS	
T_1	Chlorimuron Ethyl 25% WP @ 37.05 g a.i./ha (PoE)	6.37 (40.20)	6.40 (40.6)	6.72 (44.8)	6.75 (45.2)	74.07	23.54
T_2	Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 52.50 g a.i./ ha+ Spreadmaxa@ 0.5 ml litre-1(PoE)	5.21 (26.65)	5.16 (26.1)	5.11 (25.7)	4.82 (22.7)	77.74	6.96
T_3	Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE)	5.03 (24.70)	4.99 (24.5)	4.9 (24.32)	4.55 (20.2)	89.26	4.35
T_4	Bispyribac sodium 10% SC @ 25 ml a.i./ha (PoE)	6.02 (35.70)	5.93 (34.71)	5.11 (25.7)	5.13 (25.9)	64.07	16.52
T_5	Pyrazosulfuron 10% WP@ 215g a.i./ha (PoE)	6.05 (36.20)	6.27 (38.9)	5.87 (34)	5.42 (29)	62.96	20.00
T_6	Triafamone 20% + ethoxysulfuron10% WG @ 66.5 g a.i./ha (PoE)	6.33 (39.70)	5.29 (27.5)	5.40 (28.7)	5.2 (25.2)	72.59	14.26
T_7	Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 135 ml a.i./ha (PoE)	6.47 (41.40)	5.52 (30)	5.44 (29.2)	5.21 (26.5)	74.44	9.57
T_8	Fenoxoprop (PE) fb Halosulfuron @ (56 fb 67) ml a.i./ha (PoE)	6.46 (41.30)	5.63 (31.2)	6.92 (47.5)	6.83 (46.5)	75.93	12.17
T_9	Hand weeding (20 and 40 DAS)	0.71 (0.00)	0.71 (0)	2.91 (8)	2.79 (7.3)	100.00	0.00
T_{10}	Untreated (Control)	6.46 (41.3)	10.69 (114)	11.54 (133)	11.92 (142)	0	34.78
	SEm±	0.20	0.22	0.24	0.24	4.56	0.72
	CD at 5%	0.60	0.65	0.72	0.72	13.69	9.61

Data were subjected to square root (√× +0.5) transformation; figures in parentheses are original value

Table 2: Grain yield, straw yield, biological yield, and harvest index as affected by various Weed management practices at different stages in direct seeded rice

	Treatment	Grain yield (q ha-1)	Straw yield (q ha-1)	Biological yield (q ha-1)	Harvest index (%)
T_1	Chlorimuron Ethyl 25% WP @ 37.05 g a.i./ha (PoE)	45.95	66.73	112.69	40.78
T_2	Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 52.50 g a.i./ ha+ Spreadmaxa@ 0.5 ml litre-1(PoE)	55.92	76.59	132.51	42.20
T_3	Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE)	57.49	78.11	135.60	42.40
T_4	Bispyribac sodium 10% SC @ 25 ml a.i./ha (PoE)	50.17	70.41	120.58	41.61
T_5	Pyrazosulfuron 10% WP@ 215g a.i./ha (PoE)	48.08	68.04	116.12	41.41
T_6	Triafamone 20% + ethoxysulfuron10% WG @ 66.5 g a.i./ha (PoE)	51.53	71.61	123.14	41.85
T_7	Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 135 ml a.i./ha (PoE)	54.35	74.73	129.09	42.11
T_8	Fenoxoprop (PE) fb Halosulfuron @ (56 fb 67) ml a.i./ha (PoE)	52.78	73.50	126.28	41.80
T_9	Hand weeding (20 and 40 DAS)	60.10	80.96	141.06	42.62
T_{10}	Untreated (Control)	39.20	58.06	97.25	40.30
	SEm±	2.30	2.93	4.46	1.89
	CD at 5%	6.97	8.87	13.51	NS

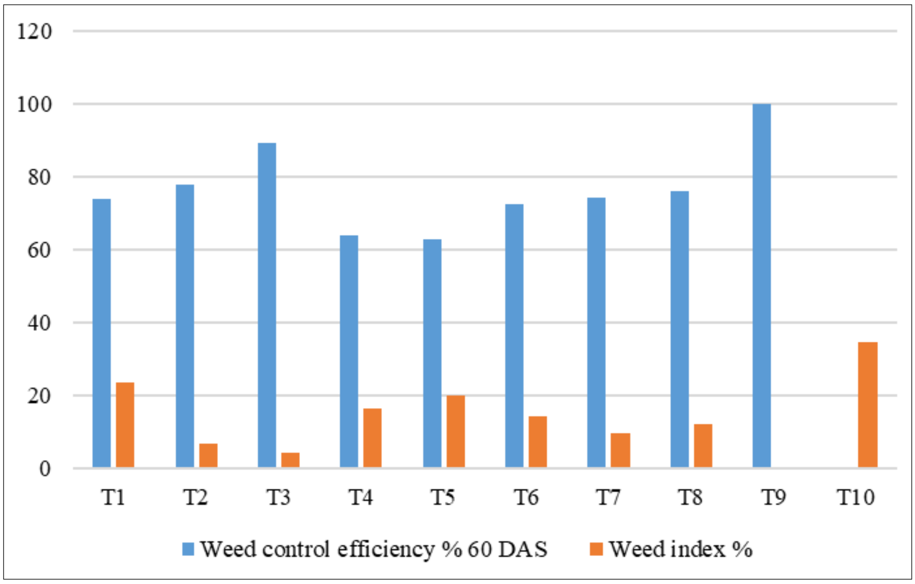

Fig 1: The density of the weed species and total weeds at all plant growth were affected significantly due to different weed control practices

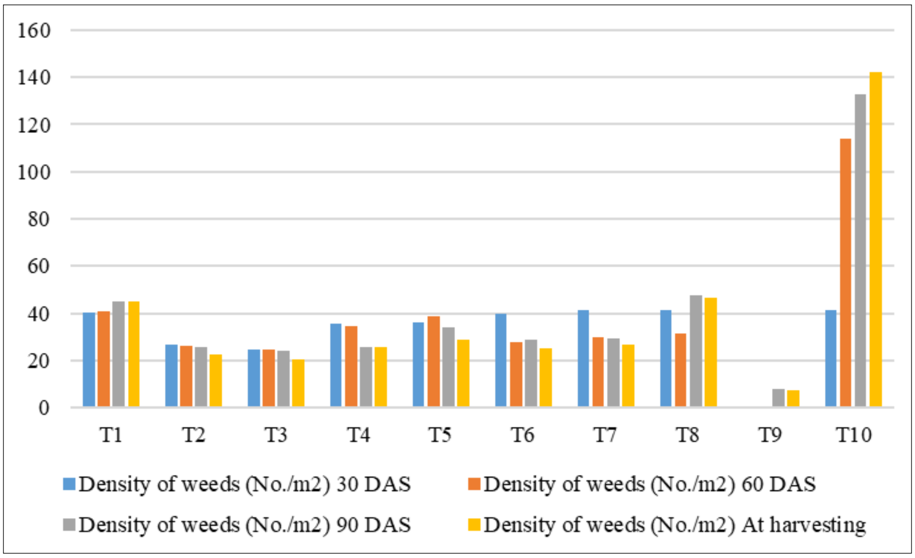

Fig 2: Indicate that highest weed control efficiency

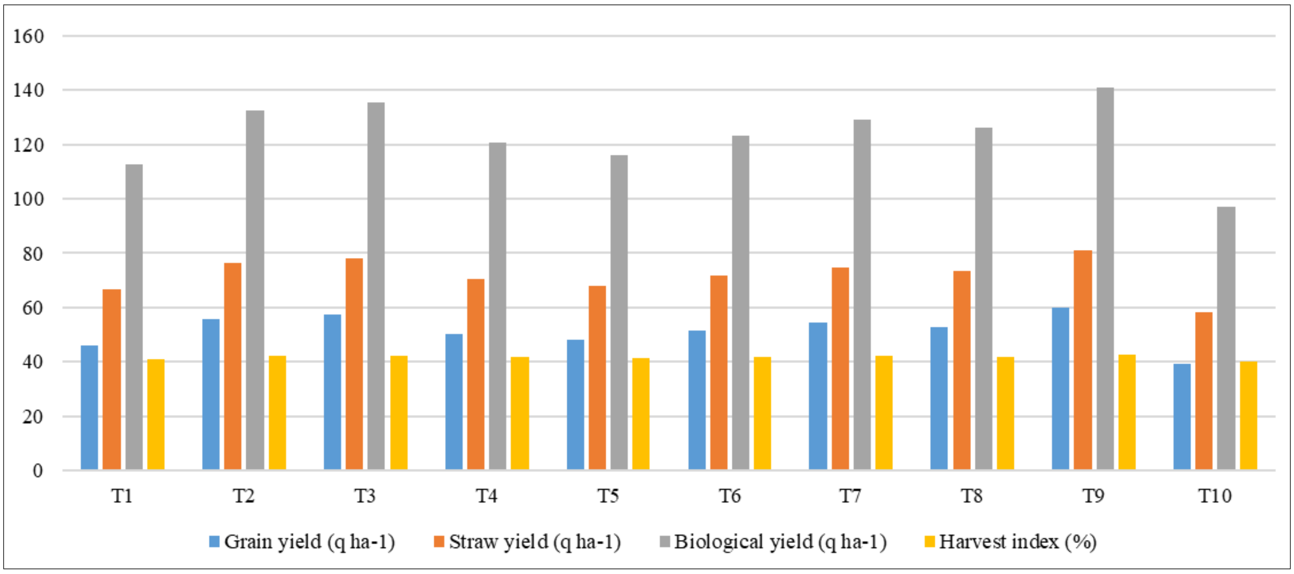

Fig 3: Indicates that various weed management practices affected the grain, straw and total biological yield significantly

Conclusion

Weeds pose a significant threat to direct-seeded rice (DSR) cultivation, affecting yields and resource utilization. Hand weeding was found to be the most effective method for controlling weeds with higher weed control efficiency and lower weed index. Among the herbicides, of Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g. a.i./ ha+ Spreadmaxa @ 0.5 ml litre-1(PoE) T_3 applied 25 days after sowing showed superior weed control efficiency, improved growth parameters, and higher yields. It is crucial to customize weed control strategies to local conditions, selecting suitable herbicides and practices that match the prevalent weed biotypes in the specific farming system.

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