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Performance of Post-Emergence Herbicide Combinations on Weed Management and Crop Yield in Direct Seeded Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Direct-seeded rice (DSR), an innovative alternative to traditional transplanting, has gained popularity for its cost-effectiveness and labour-saving attributes. Weeds pose a significant threat to DSR. In this study, the effectiveness of various weed management methods, including hand

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weeding and herbicide applications, was evaluated. Hand weeding proved most effective in controlling weeds, while specific herbicides, such as bispyribac sodium + pyrazosulfuron (T2) and triafamone + ethoxysulfuron (T6) applied at 16 days after sowing (DAS), demonstrated superior weed control efficiency, improved growth parameters, and enhanced yield. Paspalum distichum was effectively controlled by penoxsulam + cyhalofop-butyl (T7). The study emphasizes the importance of customizing weed control to local conditions, with the choice of suitable herbicides and practices aligning with prevalent weed biotypes in the specific farming system. Understanding the nuanced impacts of post-emergence herbicides is crucial in navigating the intricate landscape of weed management in direct-seeded rice.

Keywords: Hand weeding; bispyribac sodium + pyrazosulfuron; triafamone + ethoxysulfuron; weed control efficiency.

1. INTRODUCTION

In the dynamic realm of modern agriculture, rice is one of the most important crop for global food security as it is a staple food for more than 50% of the world population, providing more than 20% of the calorie intake [1]. Rice belongs to the family poaceae and it is the 5th most diverse angiosperm family in the world [2]. The increase in population and an anticipated change in dietary preferences are expected to lead to a higher demand for rice in India. The rise in rice production must come from a higher yield because rice-growing acreage is decreasing. Consequently, the sustainability of rice ecosystems and the capacity to increase production in tandem with population development while reducing water and labour use is of paramount importance. DSR, an innovative alternative to traditional transplanting methods, has gained popularity for its cost-effectiveness and labour-saving attributes. As the demand for rice production intensifies to meet the ever-growing needs of a burgeoning population, the efficient management of weeds becomes paramount to ensure optimal crop yield. Unlike conventional transplanting, where rice seedlings are grown in nurseries before being manually transplanted into flooded fields, DSR involves sowing seeds directly into prepared fields. This shift in cultivation methods brings forth a spectrum of advantages, ranging from resource conservation and labour efficiency to enhanced adaptability in diverse agroecosystems [3]. Furthermore, it enables the early establishment of wheat crops [4]. Changes in agricultural practices and techniques affect the prevalence and dispersal of weeds [5]. Similarly weeds pose a serious threat to DSR crops [6], competing for essential resources such as sunlight, water, and nutrients. Higher weed infestation in DSR, particularly in its early stages, presents a considerable challenge. In some cases, weeds have been observed to cause a substantial 90% loss in yield for DSR. Therefore, weeds emerge as the foremost biological constraint affecting the production of DSR. This underscores the critical importance of effective weed management strategies to ensure the success and productivity of DSR cultivation [7-9]. Herbicidal weed management is recognized as the most efficient method in DSR [10] and combinations of them must be strategically mixed to kill the complex weed composition in DSR. In response to these challenges, post-emergence herbicides have become integral to modern weed management strategies, allowing for selective and timely intervention to suppress weed infestations while safeguarding the health and vigour of DSR plants. As we navigate the intricate landscape of weed management in DSR, understanding the nuanced impacts of post-emergence herbicides becomes imperative.

2. MATERIALS AND METHODS

Field trials were conducted during the kharif season (2021-22) at Banaras Hindu University Agricultural Farm in Varanasi, India. The location experience semi-arid to semi-humid climate, with temperatures ranging from 28.5°C to 36°C and 1261.1 mm of total precipitation during the crop season. The soil texture is sandy clay loam soil, with a pH of 7.7 and 0.35% SOC. The experiment, replicated thrice in a Randomized Block Design, included nine weed management treatments with various herbicide dosages and combinations (Table 1). Swarna (MTU 7029) rice was directly sown at a rate of 35 kg ha^{-1} using a local furrow maker ("Kudali") with a 30 cm row spacing. Immediate irrigation followed to ensure uniform germination. Recommended nutrient doses (N:P:K-120:60:40 kg ha^{-1}) were applied using urea, diammonium phosphate and muriate of potash, and herbicides were sprayed 14 days after sowing using knapsack sprayer for post-

Table 1. Details of the treatments

S.No.	Treatment	Rate (g or ml a.i. ha^{-1})	Surfactant
T_1	Bispyribac sodium 20% + pyrazosulfuron 15% WDG	43.75 g	Spreadmax^a@ 0.5 ml $litre^{-1}$
T_2	Bispyribac sodium 20% + pyrazosulfuron 15% WDG	52.50 g	Spreadmax^a@ 0.5 ml $litre^{-1}$
T_3	Bispyribac sodium 20% + pyrazosulfuron 15% WDG	61.25 g	Spreadmax^a@ 0.5 ml $litre^{-1}$
T_4	Bispyribac sodium 10% SC	25 ml	-
T_5	Pyrazosulfuron 10% WP	15g	-
T_6	Triafamone 20% + ethoxysulfuron10% WG	66.5 g	-
T_7	Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD	135 ml	-
T_8	Hand weeding (20 and 40 DAS)	-	-
T_9	Untreated Control	-	-

emergence weed control. For rice plant biomass plants in a running metre of length is uprooted and oven dried. Whereas weed density, and biomass were assessed by randomly placing 50 cm x 50 cm quadrat at two places of each plot. Grain yield was quantified at 14% moisture content. Statistical analysis was conducted using the appropriate Analysis of Variance method, as outlined by Gomez and Gomez [11].

3. RESULTS AND DISCUSSION

We recorded 14 diverse weed flora in our experiment. Here data of 7 dominated weeds were being presented (Table: 2). Broadleaf weeds were the most dominated followed by grasses and sedges. Our findings are in line with earlier research by Mohapatra et al. [12]; Khippal et al. [13] Sanodiya and Singh [14]. Hand weeding was the best in controlling all types of weeds presented in our experiment. *Ceasulia axillaris* emerged as the most problematic weed in our experiment in terms of its growth and presence throughout the growing period. Among herbicidal treatment application of bispyribac sodium + pyrazosulfuron (T_2) and triafamone+ ethoxysulfuron (T_6) herbicides reduced the weed density of *Ceasulia axillaris, Physalis minima, Parthenium hysterophorus, Echinochloa colonum and Fimbrystylis miliacea* more effectively as compared to other herbicidal treatments. Our study is in line with findings of Hossain and Malik [15]; Kaur et al. 16]; Menon et al. [17]; Yadav et al. [18]. Whereas *Paspalum distichum* was most effectively controlled by penoxsulam+ cyhalofop-butyl (T_7). Similar result was reported by Jacob et al. [19]. All the herbicidal treatments were effective in controlling *Echinochloa colonum* and *Cyperus rotundus.* In terms of reducing total weed biomass and achieving higher weed control efficiency, bispyribac sodium + pyrazosulfuron (T_2) and triafamone+ ethoxysulfuron (T_6) emerged as the most effective herbicidal treatments (Fig. 1). Herbicide applications significantly improved plant height and rice biomass by suppressing weed competition, enhancing resource utilization by rice plants (Table 3). Notably, the herbicide treatments bispyribac sodium + pyrazosulfuron (T_2) and triafamone + ethoxysulfuron displayed superior performance in promoting crop growth, suggesting their potential to boost rice yield. Pyrazosulfuron alone exhibited the least effectiveness against weeds. Results are consistent with previous findings highlighting the limitations of using a single herbicide [20-22]. Implementing hand weeding (20 and 40 DAS) and herbicide treatments effectively reduced weed competition, optimizing resources for rice growth and, consequently, enhancing crop characteristics. In the absence of weed control, shared resources led to decreased rice biomass and plant height, impacting photosynthate assimilation. Herbicide applications mitigated weed competition, creating a more favourable environment for rice growth and resulting in increased grain yield compared to the untreated control. While manual weeding demonstrated effectiveness at specific intervals, its scalability is hindered by technical constraints like labour availability and higher labour cost involved [20,23]. Consequently, herbicide combinations, particularly bispyribac sodium + pyrazosulfuron (T_2) and triafamone + ethoxysulfuron (T_6), have emerged as practical alternatives based on yield due to their ease of use and effectiveness.

Table 2. Effects of post-emergence herbicide combinations on weed density in direct seeded rice

Treatment no		*C. axillaris*		*P. minima*		*P. hysterophorus*		*C. rotundus*		*E. colona*		*F. miliacea*		*P. distichum*	
	Rate (g or ml a.i. ha^{-1})	**30 DAS**	**75 DAS**	**30 DAS**	**75 DAS**	**30 DAS**	**75 DAS**	**30 DAS**	**75 DAS**	**30 DAS**	**75 DAS**	**30 DAS**	**75 DAS**	**30 DAS**	**75 DAS**
Bispyribac sodium 20% + pyrazosulfuron 15% WDG	43.75 g	2.7^{d}(7.3)	3.6^{ab}(13)	4.13^{b}(16.7)	2.4(5.3)	4.1^{bc} (16.3)	2.7(7)	4.3^{a}(18.7)	3.2^{b}(10)	2.7^{bcd}(7)	0.71(0)	0.71(0)	3.01^{bcd}(9)	0.71(0)	3.49^{b}(11.7)
Bispyribac sodium 20% + pyrazosulfuron 15% WDG	52.50 g	2.4^{d}(5.7)	3.17^{b}(9.7)	2.79^{c}(7.3)	2.1(4.3)	3.3^{cd} (10.3)	2.6(6.7)	4.10^{a}(16.3)	3.19^{b}(9.7)	2.48^{cd}(5.7)	0.71(0)	0.71(0)	2.97^{cd}(8.3)	0.71(0)	3.43^{b}(11.3)
Bispyribac sodium 20% + pyrazosulfuron 15% WDG	61.25 g	2.7^{d}(6.7)	3.5^{b}(12)	4.34^{b} (18.3)	2.4(5.3)	4.3^{b} (17.7)	3.02(8.7)	4.1^{a} (16.7)	3.2^{b}(10)	2.7^{bcd}(7)	0.71(0)	0.71(0)	3.02^{bcd}(8.7)	0.71(0)	3.5^{b}(12)
Bispyribac sodium 10% SC	25 ml	2.9_{cd}(8)	3.7^{ab}(14)	4.95^{b}(24)	2.5(5.7)	4.1^{b} (16.3)	2.86(7.7)	3.8^{a} (14.3)	3.39^{b}(11)	3.07^{bc}(9)	0.71(0)	0.71(0)	3.67^{ab}(13)	0.71(0)	3.1^{bc}(9.3)
Pyrazosulfuron 10% WP	15g	3.7^{bc}(13)	3.9^{ab}(15)	4.74^{b}(22)	2.3(4.7)	3.5^{bcd}(12)	2.7(6.7)	4.34^{a}(18.3)	3.34^{b}(10.7)	3.19^{b}(9.7)	0.71(0)	0.71(0)	3.58^{bc} (12.3)	0.71(0)	3.17^{bc}(9.7)
Triafamone 20% + ethoxysulfuron10% WG	66.5 g	2.4^{d}(5.3)	3.1^{b}(9.3)	4.26^{b} (17.7)	2.3(5)	3.2^{d}(10)	2.39(5.3)	3.9^{a}(15)	3.1^{b}(9.3)	2.18^{d}(4.3)	0.71(0)	0.71(0)	2.84^{d}(7.7)	0.71(0)	3.4^{b} (11.3)
Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD	135 ml	4.5^{ab}(19.7)	4.1^{ab}(16)	4.84^{b}(23)	2.4(5.3)	3.58^{bcd}(12.3)	2.4(5.3)	4.34^{a}(18.3)	3.39^{b}(11)	3.02^{bc}(8.7)	0.71(0)	0.71(0)	3.5^{bc}(12)	0.71(0)	2.8^{cd}(7.3)
Hand weeding (20 and 40 DAS)	-	1.3^{e}(1.3)	1.95^{c}(3.3)	2.04^{d}(3.7)	1.9(3.3)	1.68^{e}(2.3)	1.95(3.3)	2.3^{b}(5)	1.58^{c}(2)	1.68^{e}(2.3)	0.71(0)	0.71(0)	2.7^{d}(7)	0.71(0)	2.48^{d}(5.7)
Untreated Control	-	4.6^{a} (21.7)	4.6^{a} (20.7)	6.89^{a} (47.7)	2.9(8.3)	6.5^{a} (42.3)	2.91(8)	4.6^{a}(21)	4.1^{a}(16.3)	4.2^{a}(18)	0.71(0)	0.71(0)	4.26^{a} (17.7)	0.71(0)	4.18^{a}(17)

Data were subjected to square root ($\sqrt{x+0.5}$) transformation; figures in parentheses are original values; Letters in common are not significantly different;

Table 3. Effects of weed management treatments on growth and yield

Treatments	Rate (g or ml a.i. ha^{-1})	Plant height (cm)		Dry weight (g)	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Harvest index (H.I)
		45 DAS	100 DAS	35 DAS			
Bispyribac sodium 20% + pyrazosulfuron 15% WDG	43.75 g	40.4^{b}	76.5^{b}	20.3^{bc}	4200	9000	31.8
Bispyribac sodium 20% + pyrazosulfuron 15% WDG	52.50 g	41.8^{a}	$81a^{b}$	22.2^{ab}	5038	11000	31.4
Bispyribac sodium 20% + pyrazosulfuron 15% WDG	61.25 g	40.8^{ab}	77.5^{b}	20.6^{bc}	4929	11270	30.4
Bispyribac sodium 10% SC	25 ml	39.8^{bc}	75.5^{b}	19.8^{c}	4078	9270	30.6
Pyrazosulfuron 10% WP	15g	40.3^{b}	79.5^{ab}	19.5^{c}	3505	7130	33.0
Triafamone 20% + ethoxysulfuron10% WG	66.5 g	40.8^{ab}	80.25^{ab}	21.0^{bc}	4429	9970	30.8
Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD	135 ml	40.4^{b}	77^{b}	20.1^{bc}	4258	9270	31.5
Hand weeding (20 and 40 DAS)	-	42.0^{a}	84.5^{a}	23.2^{a}	5130	11030	31.7
Untreated Control	-	39.0^{c}	65c	16.00^{c}	2233	5000	30.9

Letters in common are not significantly different

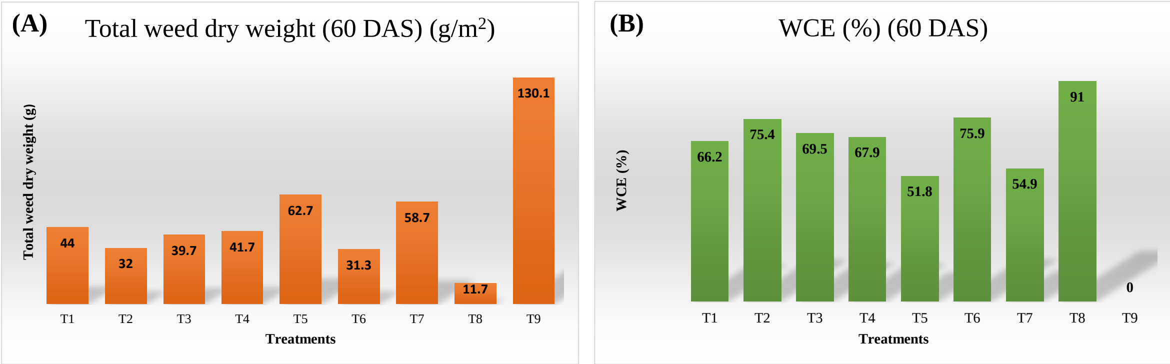

Fig. 1. Effect of post-emergence herbicide combinations on total dry weight and weed control efficiency (WCE) at 60 DAS in DSR

4. CONCLUSION

Weeds poses a threat to DSR cultivation, impacting yields and resource utilization. Hand weeding proved most effective in controlling weeds. Among the herbicides bispyribac sodium + pyrazosulfuron (T_2) and triafamone + ethoxysulfuron (T_6) applied at 16 days after sowing demonstrated superior weed control efficiency, better growth parameters and yield. Whereas *Paspalum distichum* was most effectively controlled by penoxsulam+ cyhalofop-butyl (T_7). Customizing weed control to suit local conditions is essential and the choice of suitable herbicides and practices should align with the prevalent weed biotypes in the specific farming system.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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