

Comparing the effectiveness of post-emergence herbicides application on weed control, yield attributes and yield of direct-seeded rice

NILUTPAL SAIKIA¹, MANOJ KUMAR SINGH², KADAGONDA NITHINKUMAR³, SHREYAS BAGRECHA⁴, AAKASH⁵, DENDUKURI UDAYA LAKSHMI⁶ AND SUNIL KUMAR PRAJAPATI⁷

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received: September 2024; Revised accepted: February 2025

ABSTRACT

Rice is an essential staple food that contributes significantly to global food security. Direct-seeded rice (DSR) offers advantages over traditional puddle-transplanted rice (PTR) in terms of water and labour savings. However, DSR faces significant weed management challenges that can affect yield. Herbicides have emerged as effective tools for weed management in DSR, with recommendations for using herbicide combinations and rotations to combat weed diversity and resistance. Field experiments were conducted in Varanasi (UP), India, to assess the effectiveness of post-emergence herbicides in weed management, yield attributes and yield in DSR. Nine treatments replicated thrice were tested using randomized complete block design (RBD). Based on the results of the current research, it can be inferred that the post application of bispyribac sodium 20% + pyrazosulfuron 15% WDG with a non-ionic surfactant @ 52.50 g/ha, bispyribac sodium 20% + pyrazosulfuron 15% WDG with non-ionic surfactant @ 61.25 g/ha, and triafamone 20% + ethoxysulfuron 10% WG @ 66.5 g/ha sprayed after 16 days after sowing (DAS) exhibited the most favorable growth parameters and grain yield.

Key words: Bispyribac sodium + Pyrazosulfuron, DSR, Triafamone + ethoxysulfuron, Weed management

The growing global population and the goal to increase food production by 50% by 2050, as projected by the World Resources Institute (Searchinger *et al.*, 2019), emphasize the need for a shift in agricultural practices. Rice, a crucial staple food for accounts for a significant portion of global calorie intake, ranging from 35% to 80% over half of the world's population, it contributes significantly, providing more than 20% of the calorie intake (Fukagawa and Ziska, 2019). Given its profound influence on diets, cultures, and economies worldwide, it is not an exaggeration to state that rice holds immense significance, often regarded as the essence of life. Nevertheless, the demand for rice in India is anticipated to experience a substantial

increase as a consequence of population growth and evolving dietary preferences. To meet this increased demand, rice production must be enhanced primarily through improved yields, as the available cultivation land is diminishing. Consequently, ensuring the sustainability of rice ecosystems and the ability to increase production in line with population growth, while simultaneously reducing water and labour requirements, becomes of utmost importance. DSR avoids many PTR limitations by eliminating nursery raising, seedling uprooting, transplanting, and puddling, reducing labour by up to 50% (Brown *et al.*, 2021). Additionally, DSR matures 7–10 days earlier than PTR, allowing timely planting of the next wheat crop (Yadav *et al.*, 2021). However, Weeds represent the primary biological obstacle to successful DSR, and a lack of effective weed management can result in significant grain yield reductions. To ensure the long-term sustainability of DSR, effective weed control measures utilising physical methods or herbicides during critical crop-weed competition stages are imperative. While some studies have suggested that DSR can achieve equivalent or even higher yields than TPR, thereby promoting its widespread adoption among farmers based on favorable net economic returns (Liu *et al.*, 2015), several other studies have presented contradictory findings. These studies have observed significant yield reductions in

Based on a part of M.Sc. Thesis of the first author submitted to Agricultural Farm of Banaras Hindu University, Varanasi, Uttar Pradesh in 2021 (unpublished)

¹Corresponding author's Email: nilutpalsaikia266@gmail.com, mksinghagro@bhu.ac.in

^{1,3,7}Ph.D. Scholar, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110 012; ²Professor, ⁶Ph.D. Scholar, Department of Agronomy, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005; ⁴Ph.D. Scholar, Agronomy Section, ICAR-National Dairy Research Institute, Karnal, Haryana 132 001; ⁵Assistant Professor, Department of Agronomy, R.S.M. (P.G.) College, Dhampur (Bijnor), Uttar Pradesh 246 761

DSR when compared to TPR, both in farmers' fields and experimental plots (Chen *et al.*, 2017). It is well known that weeds have the potential to dramatically shrink not only crop germination, growth and yield but also crop quality. Effective weeds management techniques are essential for the success of DSR. At present, the popularity of herbicide use in DSR is increasing due to its effectiveness, ease of application, selective control, labour savings, and cost efficiency. Due to the complexity of the weed flora in DSR, a single herbicide is frequently insufficient for weed management in DSR. In modern weed management, using herbicide combinations and rotation is an effective strategy to adapt to changing weed populations and delay herbicide resistance. Chauhan and Yadav (2013) recommend using combinations of herbicides as a key element of an effective weed control strategy in DSR. Combinations herbicide formulations contain different inhibitor mechanisms that offer broad-spectrum weed control, reducing the cost and environmental impact of herbicide applications. Our experiments was designed with two main objectives: (i) Assessing the effectiveness of post emergence herbicides (sole and pre mix combinations) for weed control, and (ii) Studying weed composition, and their effect on growth, yield attributes and yield in DSR.

Field experiment was undertaken during the *kharif* season (2021) at the Agricultural Farm of Banaras Hindu University, Varanasi, India (25°18'N latitude, 83°31'E longitude, 75.7 meters above sea level). The area experiences a semi-arid to semi-humid climate. Weekly temperatures ranged from 28.5°C to 36°C, with precipitation totaling 1261.1 mm during the crop-growing season. The sandy clay loam soil had a pH of 7.7 and contained 0.35% SOC, 203.2 kg/ha N, 18.2 kg/ha P, and 220.3 kg/ha K in the 0–15 cm soil layer. The experiment included nine weed management treatments with different herbicide dosages and combinations as follows: T₁, Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 43.75 g/ha along with Spreadmax (silicon based non-ionic surfactant) @ 0.5 ml/litre, T₂, Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 52.50 g/ha along with Spreadmax (silicon based non-ionic surfactant) @ 0.5 ml/litre, T₃, Bispyribac sodium 20% + pyrazosulfuron 15% WDG @ 61.25 g/ha along with Spreadmax (silicon based non-ionic surfactant) @ 0.5 ml/litre, T₄, Bispyribac sodium 10% SC @ 25 ml/ha, T₅, Pyrazosulfuron 10% WP@ 15 g/ha, T₆, Triafamone 20% + ethoxysulfuron 10% WG @ 66.5 g/ha, T₇, Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 135 ml/ha, T₈, Hand weeding (20 and 40 DAS); T₉, Untreated Control. It followed a RBD replicated thrice. Each plot measured 20 m² (5 m × 4 m) and was separated by 30 cm wide bunds.

Swarna (MTU 7029) rice variety was sown directly by “Kudali (a local furrow maker)” at a seed rate of 35 kg/ha

on dry soil while preserving a row spacing of 30 cm in DSR and irrigated immediately to promote uniform germination. Recommended nutrient doses (120 kg N, 60 kg P₂O₅, and 60 kg K₂O/ha) as DAP, urea, single superphosphate, and muriate of potash. Nitrogen was split into three doses (50% as a basal dose, 25% as a top dressing at tillering, and 25% at panicle initiation), and phosphorus and potassium were applied as a basal dose. Herbicides were sprayed 14 DAS with a knapsack sprayer (500 l/ha, flat fan nozzle) for post-emergence weed control. We determined rice plant biomass by measuring one-meter-long stalks in three rows per plot. Weed density and biomass were assessed at 60 DAS and harvest by arbitrarily placing two 50 cm × 50 cm quadrats in each plot. Weeds were sun-dried and oven-dried at 70°C for dry weight measurements. At harvest, we recorded rice tillers and panicles m⁻² and analyzed ten random panicles for measurements of panicle weight, and panicle length. Grain yield was quantified at 14% moisture content in kg/ha. The collected data underwent an analysis of variance following the methodology outlined by Gomez and Gomez (1984) To discern the means, the Duncan multiple range test (DMRT) was applied at a significance level of 5%, employing the (developed by IRR). Additionally, the weed biomass and density data were subjected to a square root transformation ($\sqrt{x+0.5}$).

Application of triafamone+ ethoxysulfuron and bispyribac sodium + pyrazosulfuron (T₂) herbicides reduced the weed density of *C. axillaris* by 68.4% at 60 DAS and the biomass by 88.2% compared with the non-treated treatment. Out of all the herbicides tested bispyribac sodium + pyrazosulfuron (T₂) and triafamone + ethoxysulfuron were effective in killing *E. colona*. Among the herbicidal treatments bispyribac sodium + pyrazosulfuron (T₂) and triafamone + ethoxysulfuron were more efficient in reducing the density and dry matter of *P.minima*. All the herbicide treatments reduced *F. miliacea* density by 31–53% and weed biomass by 66–77% compared with control. Triafamone + ethoxysulfuron and bispyribac sodium + pyrazosulfuron (T₂) performed best among herbicide treatments reducing biomass by 75% and 74%, respectively (Table:1). Notably, Hand weeding emerged as the most effective approach for reducing weed density and biomass in DSR. Among herbicides, the broad-spectrum herbicides bispyribac sodium + pyrazosulfuron (T₂) and triafamone + ethoxysulfuron were more effective than other treatments in controlling *C.axillaris*, *E.colona*, *P.minima* and *F.miliacea* (Table 1). This findings are consistent with prior research (Hossain *et al.*, 2017; Kaur *et al.*, 2016; Menon *et al.*, 2017; Yadav *et al.*, 2019). In contrast, penoxsulam plus cyhalofop-butyl was the most effective combination for controlling *P.distichum*. These

Table 1. Effect of weed control treatments on density and dry matter of weeds/m² at 60 DAS

Trt. No.	<i>C. axillaris</i>		<i>P. minima</i>		<i>F. miliacea</i>		<i>E. colona</i>	
	Density	Dry matter	Density	Dry matter	Density	Dry matter	Density	Dry matter
T ₁	3.9 ^{bc} (14.7)	1.9 ^{bc} (3)	2.9 ^d (8.7)	2. ^{bc} (3.7)	5.9 ^d (35)	2.7 ^{bc} (7.07)	3.7 ^{bcd} (13)	4.5 ^c (20)
T ₂	3.4 ^c (11)	1.5 ^c (1.9)	2.8 ^d (7.7)	1.7 ^c (2.52)	5.5 ^c (30)	2.6 ^{bc} (6.3)	3.2 ^{cd} (9.67)	3.7 ^{cd} (13)
T ₃	3.6 ^{bc} (12.7)	1.7 ^{bc} (2.7)	3.4 ^{bcd} (11.3)	2.3 ^{ab} (4.6)	5.7 ^e (32)	2.7 ^{bc} (6.7)	3.4 ^{bcd} (11)	4.1 ^{cd} (16.6)
T ₄	4 ^b (16.3)	1.9 ^{bc} (3.3)	4 ^{ab} (16)	2.6 ^a (6.4)	6.12 ^{cd} (37)	3 ^b (8.5)	3.9 ^{bc} (14.7)	3.8 ^{cd} (13.7)
T ₅	4.1 ^b (17)	2.2 ^b (4.2)	4 ^{abc} (16)	2.3 ^{ab} (5.)	6.3 ^{bc} (38.7)	2.9 ^{bc} (8.3)	3.9 ^b (15.3)	5.9 ^b (36)
T ₆	3.3 ^c (10.3)	1.8 ^{bc} (2.9)	3.2 ^{bcd} (9.7)	1.9 ^{bc} (3.3)	5.2 ^f (27)	2.6 ^c (6.2)	3 ^d (8.7)	3.3 ^d (10.9)
T ₇	4.3 ^b (18.3)	2.2 ^b (4.3)	3 ^{cd} (9)	1.9 ^{bc} (3.4)	6.4 ^b (40)	2.7 ^{bc} (7)	3.6 ^{bcd} (12.3)	5.9 ^b (34.3)
T ₈	1.9 ^d (3.3)	1 ^d (0.6)	1.9 ^c (3)	0.9 ^d (0.9)	4.4 ^g (19.3)	1.5 ^d (1.8)	2 ^c (4)	2.4 ^e (5.3)
T ₉	5.7 ^a (32.7)	5 ^a (24.7)	4.9 ^a (23.3)	2.6 ^a (6.6)	7.7 ^a (58.3)	5 ^a (25)	5.7 ^a (32.7)	7.3 ^a (53.7)

Figures in parentheses are original values; Letters in common are not significantly different, N.S-Non significant.

results are in line with (Sankar *et al.*, 2020). Herbicides contributed to increased tillers, plant height and panicle length compared to weedy plots. This improvement in crop growth characteristics is due to the effective suppression of weed competition, which allows rice plants to utilise available resources more efficiently (Mir *et al.*, 2023).

The hand-weeded treatment recorded taller plants (77 cm and 96 cm) at both the observations date. In comparison, weedy plots recorded the lowest plant height (43.9 cm and 85.1 cm) at both the observations date. Hand-weeded treatment recorded the highest biomass production, while weedy plots recorded the lowest. Among the herbicidal treatments, application of bispyribac sodium + pyrazosulfuron (T₂) lead to 71% and 79% higher biomass production, compared to non- treated treatment at 60 DAS and 100 DAS, respectively as against triafamone + ethoxysulfuron which increased biomass by 66% and 76% (Table: 2). The weedy plots had the lowest tiller production (Table: 2). The hand-weeding treatment increased tiller

production by 196% compared to the weedy plots. Applying bispyribac sodium + pyrazosulfuron (T₂) also resulted in substantial increases in tiller production, by 183% . The triafamone + ethoxysulfuron treatment also exhibited high tiller production. Whereas the solitary pyrazosulfuron treatment demonstrated the second-lowest tiller production after the untreated control. Analysis of the data pertaining to the number of panicle m⁻², panicle length and weight did not differ statistically among the treatments (Table: 2). Hand weeding recorded the highest grain yield, showing a 230% improvement compared to the untreated control. Following this, the plots treated with bispyribac sodium + pyrazosulfuron (T₂) and a higher dose of bispyribac sodium + pyrazosulfuron (T₃) demonstrated relatively high grain yields, followed by the triafamone + ethoxysulfuron treatment (Table: 2). Conversely, the weedy plot exhibited the lowest grain yield, followed by plots treated solely with bispyribac sodium and pyrazosulfuron (Table: 2). Similar trends were observed for straw yield (Table: 2).

Table 2. Effect of weed control treatments on growth and yield of DSR

Treatment	Plant height		Dry wt. (g)		Tiller/ m ²	Panicle Length (cm)	Panicle Weight (g)	Panicle/ m ²	Grain yield (t/ha)	Straw yield (t/ha)
	60 DAS	Harvest	60 DAS	100 DAS						
T ₁	70 ^{bc}	93.4 ^{ab}	44.6 ^d	132.5 ^{cd}	322 ^{ab}	22	2.92	292 ^{abc}	4.20 ^{ab}	9.0 ^c
T ₂	72.4 ^{ab}	95.5 ^a	50 ^b	144.3 ^b	375 ^a	21.5	2.96	341 ^a	5.04 ^a	11.0 ^a
T ₃	70.1 ^{bc}	94.1 ^{ab}	47.6 ^c	139.8 ^{bc}	373 ^a	21.4	2.91	335 ^a	4.93 ^a	11.3 ^a
T ₄	66.1 ^{cd}	90.2 ^{ab}	41.3 ^c	126.8 ^{dc}	319 ^{ab}	21.4	3.01	274 ^{bc}	4.08 ^{ab}	9.3 ^c
T ₅	65.3 ^d	90.1 ^{ab}	40.6 ^c	122.3 ^e	280 ^{bc}	21.7	2.79	257 ^c	3.51 ^b	7.1 ^d
T ₆	71 ^b	94.3 ^{ab}	48.6 ^{bc}	141.3 ^b	330 ^{ab}	21.9	2.83	322 ^{ab}	4.43 ^{ab}	9.9 ^b
T ₇	66.2 ^{cd}	92.3 ^{ab}	45.3 ^d	130.3 ^{dc}	327 ^{ab}	22	2.94	293 ^{abc}	4.26 ^{ab}	9.3 ^c
T ₈	77 ^a	96.3 ^a	53.5 ^a	154.2 ^a	400 ^a	22.7	3.12	347 ^a	5.13 ^a	11.0 ^a
T ₉	43.9 ^c	85.1 ^b	29.2 ^f	80.2 ^f	204 ^c	19.8	2.52	175 ^d	2.23 ^c	5.0 ^e
						NS	NS			

NS–Non significant

The herbicide treatments bispyribac sodium + pyrazosulfuron (T_2) and triafamone + ethoxysulfuron demonstrated superior performance in enhancing crop growth characteristics, suggesting they have the potential to enhance rice yield. Weed control efficacy is moderate for both low and high doses of bispyribac sodium + pyrazosulfuron (T_1 and T_3) and penoxsulam + cyhalofop-butyl. However, sole application of bispyribac sodium and pyrazosulfuron recorded least effectiveness against weeds in DSR. Previously Khaliq and Matloob (2011) has documented the insufficient control of weeds in DSR using a single herbicide. This is predominantly attributable to the presence of a resistant weed flora consisting of difficult-to-control weeds. Hand weeding (at 20 and 40 DAS) and herbicide treatments successfully decreased weed competition, increasing the availability of resources for rice plants and, consequently, their growth. In the absence of weed control measures, the crop and weed shared resources such as sunlight, nutrients and water. This resulted in a decrease in rice biomass, plant height, number of tillers, and panicle size due to decreased assimilation of photosynthates (Mir *et al.*, 2023). Nevertheless, herbicide application significantly increased grain yield and rice biomass accumulation compared to the weed check treatment. Herbicide applications effectively reduced weed competition, creating a more favourable environment for rice growth. Ultimately resulted in an increase in grain yield compared to the untreated control (Satapathy *et al.*, 2020). While manual weeding has shown effectiveness in weed control at specific time intervals (20 and 40 DAS), its feasibility on a large scale is hindered by technical constraints such as labour availability and productivity.

Findings suggests that bispyribac sodium 20% + pyrazosulfuron 15% WDG with a non-ionic surfactant @ 52.50 g/ha and triafamone 20% + ethoxysulfuron 10% WG @ 66.5 g/ha applied 16 DAS, offer favorable growth parameters, yield attributes and yield.

REFERENCES

- Searchinger, T., Waite, R., Hanson, C., Ranganathan, J., Dumas, P., Matthews, E. and Klirs, C. 2019. Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. Final report.
- Fukagawa, N.K. and Ziska, L.H. 2019. Rice: Importance for global nutrition. *J Nutr Sci Vitaminol* 65(Supplement), pp. S2–S3.
- Brown, B., Samaddar, A., Singh, K., Leipzig, A., Kumar, A., Kumar, P., Singh, D.K., Malik, R., Craufurd, P., Kumar, V. and McDonald, A. 2021. Understanding decision processes in becoming a fee-for-hire service provider: a case study on direct seeded rice in Bihar. *India Journal of Rural Studies* 87: pp. 254–266.
- Yadav, D.B., Yadav, A., Vats A.K., Gill, G. and Malik, R.K. 2021. Direct seeded rice in sequence with zero-tillage wheat in north-western India: addressing system-based sustainability issues. *SN Applied Sciences* 3(11): p. 844.
- Liu, H., Hussain, S., Zheng, M., Peng, S., Huang, J., Cui, K., Nie, L. 2015. Dry direct-seeded rice as an alternative to transplanted-flooded rice in central China. *Agronomy for Sustainable Development* 35: 285–294.
- Chen, S., Ge, Q., Chu, G., Xu, C., Yan, J., Zhang, X., Wang, D. 2017. Seasonal differences in the rice grain yield and nitrogen use efficiency response to seedling establishment methods in the middle and lower reaches of the Yangtze River in China. *Field Crops Research* 205: 157–169.
- Chauhan, B.S., Yadav, A. 2013. Weed management approaches for dry seeded rice in India- a review. *Indian Journal of Weed Science* 45: 1–6.
- Gomez, K.A., Gomez, A.A. 1984. Statistical procedures for agricultural research. John Wiley & sons.
- Hossain, A., Malik, G.C. 2017. Herbicides combinations for control of complex weed flora in transplanted rice in Lateritic belt of West Bengal. *Indian Journal of Weed Science* 49(3): 276–278.
- Kaur, S., Bhullar, M.S., Kaur, T. 2016. Management of mixed weed flora in transplanted rice using herbicide combinations. *Agricultural Research Journal* 53(4): 483–487.
- Menon, M.V., Bridgit, T.K., Girija, T. 2017. Efficacy of herbicide combinations for weed management in transplanted rice. *Journal of Tropical Agriculture* 54(2): 204.
- Yadav, D.B., Yadav, A., Punia, S.S. 2019. Effectiveness of triafamone+ ethoxysulfuron (pre-mix) against complex weed flora in transplanted rice and its residual effects on wheat. *Indian Journal of Weed Science* 51(2): 106–110.
- Mir, M.S., Singh, P., Bhat, T.A., Kanth, R.H., Nazir, A., Al-Ashkar, I., Kamran, M., Hadifa, A.A. and El Sabagh, A. 2023. Influence of Sowing Time and Weed Management Practices on the Performance and Weed Dynamics of Direct Drum Seeded Rice. *ACS omega* 8(29): pp. 25,861–25,876.
- Khaliq, A., Matloob, A. 2011. Weed crop competition period in three fine rice cultivars under DSR culture. *Pak. Weed Science Research* 17: 229–243.
- Satapathy, B.S., Saha, S. and Munda, S. 2020. Evaluation of herbicide mixtures for broad-spectrum weed control and yield in transplanted summer rice (*Oryza sativa*). *Indian Journal of Agronomy* 65(2): pp. 192–197.
- Sankar, S.B., Sanjoy, S. and Sushmita, M., 2020. Evaluation of herbicide mixtures for broad-spectrum weed control and yield in transplanted summer rice (*Oryza sativa*). *Indian Journal of Agronomy* 65(2): 192–197.