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Assessment of new-generation herbicides for effective weed management, yield enhancement, and economic returns in direct-seeded rice

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Abstract
This study was conducted during the *samba* season 2023 to assess the effectiveness of selected new-generation herbicide formulations for weed management in direct-seeded rice, with emphasis on crop yield and economic returns. (cv. TKM 13). The experiment was laid out in a Randomized Block Design (RBD) with ten treatments and three replications. The treatments comprised integrated weed management strategies involving pre-emergence, early post-emergence, and post-emergence herbicide applications, either alone or in combination with hand weeding, and were compared with a weedy check and hand weeding twice at 15 and 30 DAS. Pre-emergence treatments included pretilachlor, pyrazosulfuron-ethyl, and a ready-mix of pretilachlor + pyrazosulfuron-ethyl, followed by hand weeding at 15 DAS. Early post-emergence options consisted of metsulfuron-methyl, bispyribac-sodium, triafamone + ethoxysulfuron followed by hand weeding, and metsulfuron-methyl + chlorimuron-ethyl followed by hand weeding at 30 DAS, while 2,4-D was applied as a post-emergence treatment. All herbicide-based treatments resulted in a significant increase in grain yield compared with the weedy check. Although manual weeding alone proved highly effective, its field-level adoption is constrained by escalating labour costs and limited labour availability. Among the chemical interventions, the early post-emergence application of triafamone + ethoxysulfuron at 40 g A.I. ha^{-1} followed by hand weeding at 30 DAS emerged as the most effective and environmentally sustainable option. In addition to improving yield, this treatment sequence substantially enhanced economic returns, recording higher gross and net returns as well as a superior benefit-cost ratio, thereby establishing it as the most profitable and efficient weed management practice for increasing productivity in direct-seeded rice.

Keywords: Benefit-cost ratio, direct-seeded rice, integrated weed management, yield

Introduction
Rice (*Oryza sativa* L.) is among the most important staple food crops in the world, providing the major source of dietary energy for more than half of the global population. In India, rice production reached a historic high of 137.82 million tonnes during 2023-24, with an average productivity of about 2.8 t ha^{-1}, while Tamil Nadu recorded comparatively higher yields of nearly 3.5 t ha^{-1}. Beyond its quantitative contribution to food availability, rice plays a vital role in nutritional security, cultural traditions, and livelihood sustenance across India and much of Asia. Its importance as a cornerstone crop has been well documented in recent studies, emphasizing its central role in food security and rural livelihoods (Karthickraja *et al*., 2022; Kalaiarasanvenkatesan *et al*., 2024; Teja *et al*., 2024; Dharshini *et al*., 2025) [3, 2, 13, 1].
Rice is grown under a wide range of agro-ecological conditions, where the composition and dynamics of weed flora are strongly influenced by water regimes and crop establishment methods. Traditionally, puddled transplanted rice has dominated Asian rice ecosystems, as flooding and intensive tillage effectively suppress early weed emergence. However, this production system is increasingly constrained by rising labour costs, excessive water consumption, high energy requirements, declining groundwater levels, and climatic uncertainties.

In this context, direct-seeded rice (DSR) has emerged as a viable alternative, offering substantial savings in labour, water, and production costs, along with the advantage of timely sowing.

Despite these benefits, weed infestation remains the most serious challenge in DSR. The absence of standing water during the early growth stages allows weeds and rice to emerge simultaneously, making weeds the principal cause of yield loss. Uncontrolled weed growth can reduce DSR yields by 45-95%, particularly during the early growth period when crop competitiveness is low (Nath *et al*., 2024) [9]. Although manual weeding between 20 and 40 DAS is effective, its adoption in regions such as Tamil Nadu is limited by labour scarcity, high wage rates, and inconsistent labour availability. Consequently, chemical weed control has become indispensable in DSR systems. However, dependence on single herbicides often proves inadequate due to diverse weed flora, staggered weed emergence, and the risk of resistance development (Kokilam *et al*., 2016) [4]. This has led to increased emphasis on integrated herbicide strategies, including pre-emergence followed by early post-emergence applications and the use of premix or tank-mix herbicides with multiple modes of action for broader weed control and resistance management (Rastogi *et al*., 2024) [10]. New-generation premixed herbicides, particularly in DSR varieties such as TKM 13, have demonstrated superior efficacy against grasses, sedges, and broad-leaved weeds due to their synergistic action, improved crop safety, persistence, and effectiveness at lower dose. When combined with appropriate cultural practices and limited manual weeding, these approaches enhance crop establishment, tillering, leaf area development, and biomass accumulation, thereby offering a resilient, cost-effective, and sustainable pathway for improving rice productivity under prevailing resource constraints.

Materials and Methods

A field experiment was carried out during the samba season of 2023 at Field A4, Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India, using the direct-seeded rice variety TKM 13. The experimental site is geographically located at 11°24′ N latitude and 79°44′ E longitude, with an elevation of 5.79 m above mean sea level. The region is characterized by a warm, humid tropical climate. The soil of the experimental field was clay loam in texture, having an electrical conductivity of 0.89 dS m^{-1} and an organic carbon content of 0.52%. The soil reaction was slightly alkaline, with pH values ranging from 8.08 to 8.40. Initial soil analysis indicated a low available nitrogen status (225 kg ha^{-1}), medium available phosphorus (20.7 kg ha^{-1}), and high available potassium (302 kg ha^{-1}). The experiment was laid out in a Randomized Block Design (RBD) comprising ten treatments with three replications. The treatments included different weed management practices as follows: T_1-pretilachlor 30% EC at 150 g A.I. ha^{-1}; T_2-pyrazosulfuron-ethyl 10% WP at 20 g A.I. ha^{-1}; T_3-bispyribac-sodium 10% SC at 20 g A.I. ha^{-1}; T_4-metsulfuron-methyl 10% WP at 4 g A.I. ha^{-1}; T_5-2,4-D sodium salt 80% WP at 0.8 kg A.I. ha^{-1}; T_6-triafamone 20% + ethoxysulfuron 10% WG at 40 g A.I. ha^{-1} followed by hand weeding at 30 DAS; T_7-pretilachlor 30% EC at 150 g A.I. ha^{-1} + pyrazosulfuron-ethyl 0.75% WG at 3.75 g A.I. ha^{-1} followed by hand weeding at 15 DAS; T_8-metsulfuron-methyl 10% WP at 4 g A.I. ha^{-1} + chlorimuron-ethyl 10% WP at 4 g A.I. ha^{-1} followed by hand weeding; T_9-hand weeding twice at 15 and 30 DAS; and T_{10}-weedy check. To ensure a uniform crop stand, gap filling was carried out at 8 DAS. The crop was supplied with the recommended dose of fertilizers at 120:40:40 kg N: P_2O_5:K_2O ha^{-1}. Manual weeding was done on two occasions, at 15 and 30 days after sowing (DAS). Herbicides were applied using a knapsack sprayer equipped with a flat-fan nozzle, with a spray volume of 500 L ha^{-1} in accordance with the treatment schedule. Adequate irrigation was provided to maintain approximately 5 cm of standing water during the crop growth period. Water supply was withheld one week before harvest, and excess water was removed to ensure uniform crop ripening. All agronomic practices were followed as per the standard package of practices recommended for direct-seeded rice.

Biometric observations

Yield attributes such as grain and straw yields were measured biometrically across various crop growth stages. The economics of direct-seeded rice under different weed management practices were assessed using cultivation costs, gross returns, net returns, and benefit-cost ratio.

Statistical analysis

All experimental data were analyzed using the SPSS Statistical tool (Version 20.0). Statistical significance was determined by calculating the Critical Difference (CD) at the P=0.05 probability level.

Results and Discussion

Weed management practices significantly impacted the yield parameters of direct seeded rice, Table 1 clearly demonstrates the decisive influence of weed management practices on grain and straw yields of direct-seeded rice. Among the treatments evaluated, hand weeding twice at 15 and 30 DAS resulted in the highest grain yield (5080 kg ha^{-1}) and straw yield (7365 kg ha^{-1}). The superior performance of this treatment can be attributed to continuous and effective weed suppression during the critical stages of crop establishment and tillering. As reported by Nath *et al*. (2024) [9], maintaining weed-free conditions during the critical period of crop-weed competition (15-45 DAS) substantially reduces interspecific competition for nutrients, moisture, and light, thereby enhancing crop growth and yield. Similar findings were also documented by Kokilam *et al*. (2016) [4], who emphasized that timely manual weed control promotes better root development, higher leaf area index, and improved photosynthetic efficiency, ultimately leading to superior yield attributes in direct-seeded rice. Although, hand weeding is highly effective, its practical application is often constrained by high labour requirements and escalating labour costs. Nevertheless, as highlighted by Shekhawat *et al*., (2020) [11], manual weeding remains one of the most reliable methods for controlling a wide spectrum of weeds in DSR systems, especially under situations of herbicide escape or herbicide-resistant weed populations.

Closely following hand weeding twice, the early post-emergence application of triafamone + ethoxysulfuron at 40 g A.I. ha^{-1} followed by hand weeding at 30 DAS (T_6) recorded significantly higher grain and straw yields compared with other herbicidal treatments and the weedy check. The effectiveness of this integrated approach lies in its ability to suppress the initial weed flush during the most sensitive phase of crop establishment and tiller initiation. Mathew (2025) [7] reported that early post-emergence herbicides effectively reduce weed density and biomass between 10 and 30 DAS, thereby minimizing competition and allowing rice plants to achieve better tiller production and panicle development.

Table 1: Effect of weed management practices on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index in direct seeded rice

Treatments	Grain	Straw yield	Harvest index
T_1-Pretilachlor 30% Ec at 150 g a.i ha^{-1}	4039	5853	40.83
T_2-Pyrazosulfuron-ethyl 10% WP at 20 g A.I. ha^{-1}	3807	5551	40.68
T_3-Bisyribac sodium 10% SC @ 20 g A.I. ha^{-1}	4278	6178	40.91
T_4-Metsulfuron-methyl 10% WP at 4 g A.I. ha^{-1}	3567	5246	40.47
T_5-2, 4-D @ 0.5 kg A.I. ha^{-1} on 30 DAS	3227	4936	39.53
T_6-Triafamone 20% + Ethoxysulfuron 10% WG at 40 g A.I. ha^{-1} on 14 DAS *fb* Hand Weeding at 30 DAS	4848	7061	40.71
T_7-Pretilachlor 30% EC at 150 g A.I. Ha^{-1} + Pyrazosulfuron-ethyl 0.75% WG at 3.75 g A.I. ha^{-1} on 3 DAS *fb* Hand Weeding at 15 DAS	4614	6753	40.59
T_8-Metsulfuron-methyl 10% WP at 4 g A.I. Ha^{-1} + Chlorimuron-ethyl 10% WP at 4 g A.I. ha^{-1} on 14 DAS *fb* Hand Weeding at 30 DAS	4514	6503	40.97
T_9-Two hand weeding (15&30 das)	5080	7365	40.82
T_{10}-Weedy check	2150	3420	38.60
S.Ed.	130	156	0.12
CD (P=0.05)	231	316	NS

Similarly, Rastogi *et al*. (2024) [10] observed that integrating early post-emergence herbicides with limited manual weeding resulted in yield levels comparable to those obtained under repeated hand weeding, while significantly reducing labour inputs. The present findings corroborate earlier studies by Nath *et al*. (2024) [9], who reported that combining early post-emergence herbicides such as triafamone + ethoxysulfuron with a single hand weeding not only ensures effective weed control during the critical growth stages but also improves grain filling and overall productivity. Such integrated weed management strategies strike a balance between agronomic effectiveness and operational feasibility.

Overall, the present investigation indicates that although hand weeding twice remains the most effective practice for maximizing grain and straw yields in direct-seeded rice (DSR), its exclusive reliance is increasingly impractical under current farming conditions. Hand weeding ensures efficient control of diverse weed flora during the critical period of crop-weed competition, thereby minimizing competition for nutrients, moisture, and light and allowing the crop to attain its yield potential. However, this practice is highly labour-intensive, time-consuming, and costly, and its timely implementation is often constrained by labour scarcity and rising wages, particularly during peak agricultural periods. Delays in manual weeding during early crop growth can result in severe and irreversible yield losses.

In contrast, new-generation premixed herbicides provide broad-spectrum weed control and are especially effective when applied at the early post-emergence stage, suppressing the initial weed flush during 15-30 DAS. Integrating these herbicides with a single hand weeding effectively manages early and late-emerging weeds, reduces labour requirements, lowers production costs, and improves economic returns. Hence, integrated weed management combining premixed herbicides with limited manual intervention offers a more practical, economical, and scalable solution for sustainable DSR cultivation.

Economics

The economic evaluation of weed management practices (Table. 2) underscores the critical influence of weed control not only on crop performance but also on farm profitability. Among the evaluated treatments, hand weeding twice at 15 and 30 DAS (T_9) resulted in the highest gross return (₹116,332 ha^{-1}) and net return (₹62,332 ha^{-1}), reflecting its effectiveness in sustaining low weed pressure throughout the crop growth period. This aligns with findings from recent research indicating that maintaining weed-free conditions during the critical crop-weed competition period significantly enhances rice yield and economic returns, even though labour costs are high (Verma *et al*., 2024) [14].

The next best economic performance was observed in the integrated treatment involving early post-emergence application of triafamone + ethoxysulfuron at 40 g A.I. ha^{-1} at 14 DAS followed by hand weeding at 30 DAS (T_6), with gross and net returns of ₹111,084 ha^{-1} and ₹58,085 ha^{-1}, respectively. This integrated approach provided effective early weed suppression and reduced labour demand compared to repeated hand weeding. Such combined strategies are increasingly recommended in the literature, as premixed and combination herbicide treatments have been shown to reduce weed biomass substantially and improve yield and profitability in DSR systems. The treatment combining Pretilachlor 30% EC at 150 g A.I. Ha^{-1} + Pyrazosulfuron-ethyl 0.75% WG at 3.75 g A.I. ha^{-1} *fb* Hand Weeding at 15 DAS also recorded appreciable returns (gross: ₹105,788 ha^{-1}; net: ₹54,000 ha^{-1}). Although slightly lower than the top two, this practice still demonstrated that early herbicide intervention, when integrated with manual weeding, effectively enhances economic outcomes by minimizing early weed competition a trend supported by recent integrated weed management research (Manjhi *et al*., 2025) [6].

In contrast, the weedy check (T_{10}) recorded the lowest gross return (₹49,842 ha^{-1}) and net return (₹3,842 ha^{-1}), reflecting severe economic losses due to unchecked weed competition. This is consistent with widespread evidence that inadequate weed control leads to substantial yield and income losses in DSR systems, due to early resource competition between weeds and rice seedlings (Mir *et al*., 2024) [8].

In terms of benefit-cost ratio, hand weeding twice again excelled with a B:C of 2.15, followed by the triafamone + ethoxysulfuron integration (2.10). The weedy check recorded the lowest B:C ratio (1.25), emphasizing the economic inefficiency of poor weed management. These findings mirror broader economic assessments showing that effective weed control particularly when herbicides are combined with limited manual weeding improves profitability by reducing labour costs and enhancing yields (Verma *et al*., 2024) [14].

Overall, the study highlights that effective weed management is fundamental to achieving higher productivity and profitability in direct-seeded rice. Hand weeding twice at 15 and 30 DAS ensured superior grain and straw yields due to sustained weed control during the critical competition period, but its widespread adoption is limited by labour scarcity and high costs.

Table 2: Evaluating the economics of emerging herbicide formulations in direct-seeded rice

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	BCR
T_1-Pretilachlor 30% Ec at 150 g a.i ha^{-1}	49050	92488	43438	1.89
T_2-Pyrazosulfuron-ethyl 10% WP at 20 g A.I. ha^{-1}	49050	87244	38194	1.78
T_3-Bisyribac sodium 10% SC @ 20 g A.I. ha^{-1}	50400	97918	47518	1.94
T_4-Metsulfuron-methyl 10% WP at 4 g A.I. ha^{-1}	51600	81834	30234	1.59
T_5-2, 4-D @ 0.5 kg A.I. ha^{-1} on 30 DAS	50250	74414	24164	1.48
T_6-Triafamone 20% + Ethoxysulfuron 10% WG at 40 g A.I. ha^{-1} on 14 DAS *fb* Hand Weeding at 30 DAS	52999	111084	58085	2.10
T_7-Pretilachlor 30% EC at 150 g A.I. Ha^{-1} + Pyrazosulfuron-ethyl 0.75% WG at 3.75 g A.I. ha^{-1} on 3 DAS *fb* Hand Weeding at 15 DAS	51788	105788	54000.5	2.04
T_8-Metsulfuron-methyl 10% WP at 4 g A.I. Ha^{-1} + Chlorimuron-ethyl 10% WP at 4 g A.I. ha^{-1} on 14 DAS *fb* Hand Weeding at 30 DAS	52460	103288	50828	1.97
T_9-Two hand weeding (15&30 das)	54000	116332	62332	2.15
T_{10}-Weedy check	46000	49842	3842	1.08

In this regard, new-generation herbicides play a crucial role in enhancing weed control efficiency and feasibility. Integrated weed management, particularly the early post-emergence application of triafamone + ethoxysulfuron followed by a single hand weeding, effectively managed early and late-emerging weeds and produced yields and economic returns comparable to repeated manual weeding. The poor performance of the weedy check emphasized the magnitude of losses due to inadequate weed control. Overall, integrating new-generation herbicides with limited manual intervention offers a practical, economical, and sustainable approach for direct-seeded rice under prevailing labour and resource constraints.

Conclusion

Effective weed management is crucial for enhancing yield and profitability in direct-seeded rice. Hand weeding twice at 15 and 30 DAS produced the highest grain and straw yields due to efficient weed control during the critical crop-weed competition period however, its adoption is limited by high labour demand, rising costs, and labour scarcity. New-generation herbicides play a vital role in overcoming these constraints by ensuring timely and effective weed suppression with reduced labour dependency. Integrated weed management, particularly early post-emergence application of triafamone + ethoxysulfuron followed by a single hand weeding, effectively controlled early and late-emerging weeds and achieved yields and economic returns comparable to repeated manual weeding. This approach reduced production costs, improved benefit-cost ratios, and offers a practical, economical, and sustainable solution for direct-seeded rice cultivation.

References

1. Dharshini KA, Sudhakar P, Manimaran S, Venkatakrishnan D. Characterizing the influence of zinc, iron and silicon on growth dynamics and yield optimization in transplanted rice. Ecol Environ Conserv. 2025;31:1-8.
2. Kalaiarasanvenkatesan E, Elankavi S, Sudhakar P, Elango R. Influence of different agronomic strategies on growth and yield of rice. J Agric Ecol. 2024;7(Spec Iss 9).
3. Karthickraja M, Sudhakar P, Ramesh S, Kumar BS. Evaluation of rice varieties for growth and yield performance in aerobic cultivation. Int J Plant Soil Sci. 2022;34:532-8.
4. Kokilam MV, Suresh S, Ravi V. Weed dynamics and productivity of direct wet-seeded rice. Indian J Agric Res. 2016;50(6):521-6.
5. Mahajan G, Chauhan BS. Weed biology: A required foundation for effective weed management. Weeds. J Asian-Pacific Weed Sci Soc. 2020;2(1).
6. Manjhi RP, Meeta K, Satish KP. Efficacy of integrated weed management practices on weed dynamics, production and productivity of direct-seeded rice. Indian J Weed Sci. 2025;57(1).
7. Mathew AT, Prabukumar G, Muniyandi S, Babu RRPV, Muthaiyan G, *et al*. Impact of herbicide combinations on weed dynamics, crop productivity and economics in wet direct-seeded rice ecosystem. Crop Prot; 2025, 178.
8. Mir MS, Singh P, Kanth RH, Shah ZA, Dar EA, *et al*. Influence of sowing dates and weed management practices on weed dynamics, productivity and profitability of direct-seeded rice. Sci Rep. 2024;14(1):18877.
9. Nath CP, Singh RG, Choudhary VK, Datta D, Nandan R, *et al*. Challenges and alternatives of herbicide-based weed management. Agronomy. 2024;14(1):126.
10. Rastogi A, Kumar S, Singh P. Integrated use of early post-emergence herbicides and manual weeding in direct-seeded rice. Crop Prot. 2024;174:106327.
11. Shekhawat K, Rathore SS, Chauhan BS. Weed management in dry direct-seeded rice: A review on challenges and opportunities for sustainable rice production. Agronomy. 2020;10(9):1264.
12. Sivakumar C, Krishnaveni A, Pandiyan M. Weed management practices in direct-seeded rice ecosystem in north western zone of Tamil Nadu. Environ Conserv J. 2019;20(3):145-151.
13. Teja M, Sudhakar P, Manimaran S, Parthasarathi R. Standardizing foliar application of nano nutrients to augment rice (*Oryza sativa* L.) productivity. Indian J Appl Pure Biol. 2024;39(2):889-895.
14. Verma NK, Chitale S, Tiwari N. Effect of herbicidal weed management on crop growth, weed density, weed biomass, yield and economics of direct-seeded rice (*Oryza sativa* L.): A review. J Exp Agric Int. 2024;46(11):255-266.