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Optimizing Weed Management Approaches in Direct-seeded Rice Through New-generation Herbicides

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ABSTRACT

Direct-seeded rice (DSR) is emerging as a sustainable alternative to transplanted rice owing to its lower water requirement, reduced labour dependency and decreased production costs; however, heavy weed infestation remains a major yield-limiting factor. A field experiment was conducted during *samba* season (August-December, 2023) with the rice variety TKM 13 at the Experimental Farm of the Department of Agronomy, Annamalai University, to evaluate different weed management strategies in DSR. The study comprised eight treatments involving combinations of pre-emergence, early post-emergence, and post-emergence herbicides integrated with hand weeding, along with a weedy check and hand weeding twice at 15 and 30 DAS, laid out in a randomized block design. Pre-emergence applications included pretilachlor, pyrazosulfuron-ethyl, and their ready-mix followed by hand weeding at 15 DAS, while early post-emergence treatments involved metsulfuron-methyl, bispyribac-sodium, triafamone + ethoxysulfuron, and metsulfuron-methyl + chlorimuron-ethyl with hand weeding at 30 DAS; 2,4-D was applied as a post-emergence herbicide. Herbicide-based treatments significantly reduced weed infestation, lowering weed biomass by 58–98% at 50 DAS. Among the treatments, triafamone + ethoxysulfuron followed by hand weeding at 30 DAS was most effective, achieving 90.8–96.7% weed control efficiency and producing higher grain yield (3667–5080 kg ha^{-1}). The study concludes that integration of new-generation herbicides with cultural practices is an effective strategy for improving weed control,and productivity in direct-seeded rice systems.

***Keywords**: Direct seeded, New generation Herbicides, Rice, Weed flora.*

Introduction

Rice (*Oryza sativa* L.) is a vital staple cereal crop, serving as the primary food for more than half of the world's population and forming the cornerstone of diet, culture, and food security in India and much of Asia (Dharshini *et al.,* 2025; Teja *et al.,* 2024; Kalaiarasanvenkatesan *et al.,* 2024; Karthickraja *et al.,* 2022). Conventional puddled transplanted rice is increasingly constrained by rising labour costs, limited water availability, and delays in crop establishment. In this context, direct-seeded rice (DSR) has emerged as an efficient alternative, offering savings in labour and water, timely sowing, and improved resource-use efficiency (Kumar *et al.*, 2020; Chauhan *et al.*, 2021). However, severe weed infestation during early crop growth remains a major limitation to DSR adoption due to the absence of standing water

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([1]Ph.D Scholar, [2]Associate Professor, [3]Professor, [4]Associate Professor, [5]Professor) and slow initial crop growth, which favour the proliferation of grasses, sedges, and broad-leaved weeds (Chauhan and Johnson, 2019; Singh *et al*., 2022).

Although manual weeding is effective, labour scarcity and high costs have reduced its feasibility, making chemical weed management essential in DSR systems (Rao *et al*., 2021). Conventional herbicides often provide inadequate control because of their narrow weed spectrum and increasing resistance issues (Gogoi *et al*., 2022). In contrast, new-generation herbicides, characterized by low application rates, improved selectivity, and diverse modes of action, offer broader weed control and better compatibility with mechanized farming (Mahajan *et al*., 2020; Kaur *et al*., 2023). Their performance, however, depends on weed composition, application timing, and environmental conditions (Singh *et al*., 2021). Effective DSR weed management therefore relies on the appropriate use of pre-emergence, early post-emergence, and post-emergence herbicides, including combination formulations such as triafamone + ethoxysulfuron, which have shown improved weed suppression, crop establishment, and yield (Tripathi *et al*., 2023; Jehangir *et al*., 2024). Evaluation through weed indices such as weed density, weed dry matter, and weed control efficiency provides a reliable assessment of treatment performance. The adoption of low-dose, high-efficacy herbicides also reduces production costs and environmental risks, justifying the need for the present study under lowland DSR conditions (Kaur *et al*., 2025).

Materials and Methods

To assess the effectiveness of next-generation herbicides on weed dynamics, a field investigation was conducted at Field A4, Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India, during the *samba* season (August - December 2023) by using TKM 13 rice variety. The experimental location is +5.79 meters above mean sea level and is located at latitude 11°24' N and longitude 79°44' E. The statistical design used for research was RBD (randomized block design) with ten treatments and three replications. The treatment details are *viz*., T_1 – Pretilachlor 30% EC 150 g a.i. ha^{-1} on 3 DAS, T_2 – Pyrazosulfuron ethyl 10% WP @ 20 g a.i. ha^{-1} on 3 DAS, T_3 – Bisyribac sodium 10% SC @ 20 g a.i. ha^{-1} on 14 DAS, T_4 – Metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} on 14 DAS^{-1}, T_5 – 2,4-D sodium salt 80% WP @0.8 kg a.i. ha^{-1} on 25 DAS, T_6 – Triafamone 20% + Ethoxysulfuron 10%WG @ 40 g a.i. ha^{-1} on 14 DAS *fb* Hand Weeding on 30 DAS, T_7 – Pretilachlor 30% @150 g a.i. ha^{-1} + Pyrazosulfuron 0.75% WG ethyl @ 3.75 g a.i. ha^{-1} on 3 DAS *fb* Hand Weeding on 15DAS, T_8 - Metsulfuron methyl 10% @ 4 g a.i. ha^{-1} + chlorimuron ethyl 10% WP @ 4 g a.i. ha^{-1} on 14 DAS *fb* Hand Weeding on 30 DAS, T_9 – Two Hand Weeding (15 & 30 DAS), T_{10} – Weedy check. To maintain a uniform plant stand in broadcast direct-seeded rice, gap filling was performed at 8 DAS by dibbling pre-germinated seeds in sparsely populated or vacant areas of the field after providing light irrigation to ensure rapid establishment. Herbicides were applied according to the treatment schedule using a knapsack sprayer fitted with a flood-jet deflector nozzle, with a spray volume of 500 L ha^{-1} for pre-emergence and 375 L ha^{-1} for post-emergence applications. For soil-applied treatments, the calculated quantity of herbicide was thoroughly mixed with sand and evenly broadcast over the field to achieve uniform distribution.

Data collection

Using quadrats (0.5 m × 0.5 m), observations on weed density and weed dry weight were recorded from representative areas of each plot at 25, and 50 days after sowing (DAS) in direct-seeded rice. The collected weed samples were initially shade-dried and subsequently oven-dried at 60 °C until a constant weight was attained for dry matter estimation. Weed count data were square root-transformed using the formula ($\sqrt{\leq} x + 0.5$) to stabilize variance, and all observations were subjected to statistical analysis using ANOVA in Agres software, with differences considered significant at $p \leq 0.05$.

Weed control indices

A. Weed control efficiency (WCE)

The effectiveness of weed control (WCE) is determined by comparing the weed population in treated plots to that in untreated (control) plots. The formula by Verma *et al*. (2024) used to calculate WCE is as follows

$$\text{WCE} = \frac{\text{WPC} - \text{WPT}}{\text{WPC}} \times 100$$

Where,

WPC = Weed population in the control plot
WPT = Weed population in the treated plot

Weed control index (WCI)

The weed control index (WCI) is calculated based on the reduction in weed dry weight in the treated plot relative to the dry weight reduction in the untreated (control) plot. The following formula is used to calculate WCI as suggested by Verma *et al*. (2024).

$$\text{WCI} = \frac{\text{WC} - \text{WT}}{\text{WC}} \times 100$$

Where,
WC = Dry weight of weeds in the control plot
WT = Dry weight of weeds in the treated plot

Weed dry matter production

For weed dry matter production, weeds were collected by randomly placing 0.25 m^2 quadrants in field on 25 and 50 DAS. The weeds were removed from field and cleaned, kept under the sun for few hours and kept in hot air oven drying at 80 ^{0}C±5 ^{0}C for 48 hours. The samples were cooled in shaded area and weed biomass was converted in g m^{-2}.

Results and Discussion

Weed floristic composition

Weed flora observed during the crop growth period (*samba*, 2023), comprised three taxonomic groups, including grasses, sedges, and broad-leaved weeds. Among the grasses, *Echinochloa colona*, *Echinochloa crus-galli*, and *Leptochloa chinensis* were predominant. The major broad-leaved weeds recorded were *Bergia capensis*, *Eclipta alba*, and *Sphenoclea zeylanica*, while the sedge species included *Cyperus rotundus*, *Cyperus difformis*, and *Cyperus iria*.

Weed density and dry weight

In comparison with the weedy check, all weed management treatments significantly reduced the density and biomass of grasses, sedges, and broad-leaved weeds, leading to a marked decline in total weed population and weed dry matter at 25 and 50 DAS (Table 1) (Premnath *et al*., 2024). Considerable variation in weed flora among treatments was observed, which may be attributed to differences in herbicide type, dosage, and timing of application (Rastogi *et al*., 2024). The weedy check recorded the highest level of weed infestation, while 2,4-D was effective mainly against broad-leaved weeds but showed limited effectiveness at early crop stages and poor control of grasses and sedges (Nayak *et al*., 2018). Hand weeding twice at 15 and 30 DAS was comparable with the treatment that registered the minimum weed population; similarly, the pre-emergence application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG at 3 DAS followed by hand weeding at 15 DAS provided weed control on par with hand weeding alone (Yadav *et al*., 2018). Early post-emergence (EPOE) treatments significantly influenced total weed density (Table 1), with triafamone + ethoxysulfuron @ 40 g a.i. ha^{-1} applied at 14 DAS followed by hand weeding at 30 DAS consistently recording the lowest weed density and weed dry matter at both 25 and 50 DAS (Kaur *et al*., 2025). The weedy check T_{10} showed the highest weed density and biomass at these stages due to unchecked weed growth and efficient utilization of available resources, resulting in greater biomass accumulation, which corroborates the findings of Premnath *et al*. (2024) (Islam *et al*., 2024). Application at 3 DAS effectively suppresses weed emergence at the initial stage, thereby minimising early competition for nutrients, moisture, and light (Menon *et al*., 2019). The combined use of pretilachlor and pyrazosulfuron-ethyl reduces reliance on repeated manual weeding, which is often limited by labour scarcity in direct-seeded rice systems (Singh and Sharma, 2022). Pretilachlor restricts the emergence of germinating grassy weeds and certain sedges by inhibiting early cell division and shoot elongation, while pyrazosulfuron-ethyl, through its systemic inhibition of the ALS enzyme, efficiently controls sedges and broad-leaved weeds even at low application rates (Tomar *et al*., 2019).

Together, this herbicide combination offers broad-spectrum weed control during the most sensitive phase of weed establishment (Ameta and Ameta, 2021). Subsequent hand weeding at 15 DAS removes late-emerging and herbicide-tolerant weeds, preventing regrowth and further reducing weed biomass, thereby maintaining a nearly weed-free environment during the critical crop–weed competition period (15 – 45 DAS) (Premnath *et al*., 2024). Similarly, the early post-emergence application of triafamone + ethoxysulfuron @ 40 g a.i. ha^{-1} at 14 DAS markedly reduced weed density and biomass due to its complementary and systemic mode of action (Rastogi *et al*., 2024). Both herbicides inhibit the ALS enzyme, disrupting amino acid synthesis

Table 1. Effect of different weed management practices using new-generation herbicides on total weed density (No. m^{-2}), weed dry matter production (g m^{-2}), in direct-seeded rice

Treatments	Total weed count (No.m^{-2}) 25 DAS			Total weed count (No.m^{-2}) 50 DAS			Weed dry matter production(g m^{-2})	
	Grasses	Sedges	Broad leaved weeds	Grasses	Sedges	Broad leaved weeds	25 DAS	50 DAS
T_1 – Pretilachlor 30% EC 150 g a.i. ha^{-1} on 3 DAS	2.67(6.64)	3.35(10.70)	3.65(12.85)	4.11(16.40)	4.91(23.64)	4.23(17.38)	5.04(24.91)	8.32(68.73)
T_2 – Pyrazosulfuron ethyl 10% WP @ 20 g a.i. ha^{-1} on 3 DAS	2.90(7.92)	3.19(9.69)	2.94(8.15)	5.04(24.91)	4.00(15.48)	3.98(15.31)	5.12(25.76)	7.61(57.42)
T_3 – Bisyribac sodium 10% SC @ 20 g a.i. ha^{-1} on 14 DAS	2.41(5.30)	2.94(8.14)	3.46(11.47)	3.66(12.87)	4.38(18.71)	3.73(13.41)	5.54(30.19)	6.72(44.69)
T_4 – Metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} on 14 DAS	4.32(18.14)	3.65(12.80)	2.59(6.21)	6.27(38.85)	4.60(20.62)	3.12(9.26)	6.14(37.15)	7.50(55.70)
T_5 – 2,4-D sodium salt 80% WP @0.8 kg a.i. ha^{-1} on 25 DAS	8.74 (75.90)	7.17 (50.92)	5.90 (34.33)	9.27 (95.80)	7.89 (62.46)	2.86 (7.70)	12.71 (161.15)	12.46 (165.96)
T_6 -Triafamone 20% + Ethoxysulfuron 10%WG @ 40 g a.i. ha^{-1} on 14 DAS *fb* Hand Weeding on 30 DAS	2.13(4.03)	2.22(4.41)	2.09(3.85)	2.88(7.80)	3.01(8.58)	2.69(6.73)	3.58(12.29)	4.86(23.11)
T_7 – Pretilachlor 30% @150 g a.i. ha^{-1} + Pyrazosulfuron 0.75% WG ethyl @ 3.75 g a.i. ha^{-1} on 3 DAS*fb* Hand Weeding on 15DAS	1.32(1.25)	1.45(1.60)	1.59(2.03)	3.33(10.58)	3.71(13.24)	3.50(11.75)	2.32(4.88)	6.01(35.57)
T_8 – Metsulfuron methyl 10% @ 4 g a.i. ha^{-1} + chlorimuron ethyl 10% WP @ 4 g a.i. ha^{-1} on 14 DAS *fb* Hand Weeding on 30 DAS	3.62(12.64)	2.64(6.49)	2.31(4.84)	3.01(8.58)	3.08(9.00)	2.73(6.97)	4.95(23.97)	5.00(24.55)
T_9 – Two Hand Weeding (15&30 DAS)	1.27(1.11)	1.34(1.30)	1.48(1.68)	2.79(7.31)	2.93(8.06)	2.64(6.45)	2.14(4.09)	4.72(21.82)
T_{10} – Weedy check	8.75 (76.01)	7.18 (51.06)	5.91 (34.41)	9.90 (97.46)	8.13 (65.59)	6.79 (45.54)	12.73 (161.48)	14.46 (208.59)
S. Ed	0.14	0.16	0.17	0.70	0.77	0.91	0.20	0.29
CD(p=0.05)	0.30	0.35	0.38	1.51	1.67	1.97	0.41	0.58

*The values in parenthesis are original values and subjected to square root transformation ($\sqrt{x+0.5}$).

and consequently halting protein formation, cell division, and weed growth, which results in severe stunting or death of susceptible weeds (Nayak *et al*., 2018). Their systemic properties enable rapid foliar uptake and movement to active growth sites, ensuring effective control of grasses, sedges, and broad-leaved weeds during early crop growth (Yadav *et al*., 2018). Follow-up hand weeding at 30 DAS eliminated late-emerging and herbicide-escaped weeds, preventing secondary flushes and sustaining low weed pressure during the critical competition period, thereby enhancing crop growth and resource-use efficiency in direct-seeded rice (Menon *et al*., 2019).

Weed control efficiency

Weed control efficiency (WCE) varied significantly among treatments, with values at 25 DAS ranging from 77.31% to 97.06% (Table 2). The highest WCE occurred with two hand weedings at 15 and 30 DAS (T9), which effectively suppressed grasses, sedges, and broad-leaved weeds, achieving maximum values of 98.53%, 97.43%, and 95.24%, respectively, at 25 DAS. This treatment performed on par with pre-emergence application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG at 3 DAS followed by hand weeding at 15 DAS. Among early post-emergence (EPOE) options, T_6 (triafamone + ethoxysulfuron at 40 g a.i. ha^{-1} at 14 DAS followed by hand weeding at 30 DAS) showed the strongest results at 25 DAS, with 94.68% for grasses, 91.40% for sedges, and 88.55% for broad-leaved weeds. Hand weeding's superiority stems from its complete removal of weeds, lowering density and biomass, as noted by (Tomar *et al*., 2021). The weedy check (T_{10}) had the lowest WCE due to unchecked growth, aligning with findings by Singh and Sharma (2022). At 50 DAS, WCE ranged from 69.04% to 88.55%, with (T_9) again delivering top suppression via two hand weedings at 15 and 30 DAS, recording 92.49% for grasses, 87.67% for sedges, and 85.51% for broad-leaved weeds. (T_6) followed closely, with 89.87% for grasses, 86.86% for sedges, and 84.87% for broad-leaved weeds. The weedy check (T_{10}) exhibited the poorest performance from uncontrolled proliferation. Integrating chemical and mechanical methods remains essential for sustainable weed management in rice.

The pre-emergence mixture of pretilachlor and pyrazosulfuron-ethyl provides broad-spectrum suppression against grassy, sedge, and broadleaf weeds by blocking seedling emergence and interfering with essential amino acid production in young weeds, promoting early crop dominance (Yadav *et al*., 2018). Follow-up early post-emergence application of triafamone + ethoxysulfuron targets subsequent weed flushes that evade initial control, enhancing overall suppression (Bhattacharya *et al*., 2022). By blocking the acetolactate synthase (ALS) enzyme, both compounds disrupt branched-chain amino acid biosynthesis, stunting weed development and leading to necrosis in treated plants (Das *et al*., 2023). This systemic translocation facilitates thorough absorption through foliage and roots, delivering active ingredients to meristematic zones for reliable kill (Gaines *et al*., 2020). Combining these herbicides with timely hand weeding eliminates survivors and prevents reinfestation, extending clean periods and boosting rice vigor and yields in direct-seeded systems (Nongmaithem *et al*., 2024).

Weed control index and grain yield

Weed control index and grain yield were significantly influenced by weed management practices, highlighting the need for timely intervention during the critical crop-weed competition phase in direct-seeded rice (Table 2) (Sen *et al*., 2020).

Table 2. Effect of different weed management practices using new-generation herbicides on weed control efficiency (%) and weed control index (%) and grain yield in direct seeded rice

Treatments	Weed control efficiency (%)			Weed control efficiency (%)			Weed control index (%)		Grain yield
	25 DAS			50 DAS			25 DAS	50 DAS	
	Grasses	Sedges	Broad leaved weeds	Grasses	Sedges	Broad leaved weeds			
T_1 – Pretilachlor 30% EC 150 g a.i. ha^{-1} on 3 DAS	91.20	78.50	61.55	78.86	63.26	60.63	81.30	67.05	4039
T_2 – Pyrazosulfuron ethyl 10% WP @ 20 g a.i. ha^{-1} on 3 DAS	89.43	80.57	77.17	74.19	75.89	65.22	84.05	72.47	3807
T_3 – Bisyribac sodium 10% SC @ 20 g a.i. ha^{-1} on 14 DAS	93.00	83.70	65.51	82.45	70.79	69.50	84.57	78.58	4278
T_4 – Metsulfuron methyl 10% WP @ 4 g a.i. ha^{-1} on 14 DAS	76.08	74.22	81.65	60.07	67.97	79.09	76.99	73.30	3567
T_5 – 2,4-D sodium salt 80% WP @0.8 kg a.i. ha^{-1} on 25 DAS	0.14	0.27	0.24	16.54	5.00	82.62	0.20	20.44	3227
T_6 -Triafamone 20% + Ethoxysulfuron 10%WG @ 40 g a.i. ha^{-1} on 14 DAS *fb* Hand Weeding on 30 DAS	94.68	91.40	88.55	89.87	86.86	84.87	92.39	88.92	4848
T_7 – Pretilachlor 30% @150 g a.i. ha^{-1} + Pyrazosulfuron 0.75% WG ethyl @ 3.75 g a.i. ha^{-1} on 3 DAS*fb* Hand Weeding on 15 DAS	98.34	96.82	94.16	84.99	79.37	73.17	96.98	82.95	4614
T_8 – Metsulfuron methyl 10% @ 4 g a.i. ha^{-1} + chlorimuron ethyl 10% WP @ 4 g a.i. ha^{-1} on 14 DAS *fb* Hand Weeding on 30 DAS	83.34	87.03	85.58	87.00	86.21	84.36	85.16	88.23	4514
T_9 – Two Hand Weeding (15 & 30 DAS)	98.53	97.43	95.24	92.49	87.67	85.51	97.47	89.54	5080
T_{10} – Weedy check	-	-	-	-	-	-	0.00	0.00	2729
S. Ed	-	-	-	-	-	-	-	-	130.5
CD(p=0.05)	-	-	-	-	-	-	-	-	231.0

Hand weeding twice at 15 and 30 DAS achieved the highest weed control index through thorough physical weed removal across grasses, sedges, and broadleaved species, minimizing early nutrient/moisture/light competition and preventing tillering-stage reinfestation for optimal assimilate allocation and yield (Kokilam *et al*., 2016). The triafamone + ethoxysulfuron followed by hand weeding at 30 DAS matched double hand weeding in weed control index and grain yield, validating integrated herbicide-mechanical strategies (Choudhary *et al*., 2025). Triafamone and ethoxysulfuron's ALS inhibition curtailed amino acid synthesis in emerging weeds, slashing density/biomass early while follow-up weeding addressed escapes (Sen *et al*., 2020). Although double hand weeding recorded the highest level of weed control, the integrated herbicide–hand weeding approach achieved comparable grain yield with substantially lower labor requirement (Nongmaithem *et al*., 2024). Overall, these findings indicate that the integration of new-generation herbicides with timely hand weeding constitutes an efficient and sustainable weed management strategy for improving weed control index and grain yield in direct-seeded rice, particularly under conditions of labor scarcity (Parthipan *et al*., 2024).

Conclusion

The results of the field study clearly indicated that weed management practices exerted a significant influence on weed control efficiency, weed control index, and grain yield in direct-seeded rice. While hand weeding at 15 and 30 DAS achieved maximum weed suppression and yield, its widespread adoption is often limited by labour shortages, increased costs, and difficulties in timely execution during peak cropping periods, thereby highlighting the need for effective new-generation herbicides. Among the chemical treatments evaluated, early post-emergence application of triafamone + ethoxysulfuron @ 40 g a.i. ha^{-1} at 14 DAS followed by hand weeding at 30 DAS was particularly effective in minimizing weed density and dry matter accumulation, producing grain yields comparable to double hand weeding with substantially lower labour input. Importantly, this treatment did not adversely affect soil microbial populations, demonstrating its environmental compatibility. Hence, the integrated use of new-generation herbicides with limited hand weeding can be recommended as a sustainable, efficient, and economically feasible weed management strategy for direct-seeded rice.

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Conflict of Interest -On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

Ameta, S.K. and Ameta, S.C. 2021. Eco-friendly approaches of using weeds for sustainable plant growth and production. In *Plant Performance Under Environmental Stress: Hormones, Biostimulants and Sustainable Plant Growth Management* (pp. 559-592). Cham: Springer International Publishing.

Bhattacharya, U., Ghosh, A., Sarkar, S. and Maity, S. 2025. Response of Rice (*Oryza sativa* L.) to Weed Management Methods in the Lower Gangetic Plain Zone. *Indian Journal of Agricultural Research*. 59(1).

Chauhan, B.S. and Johnson, D.E. 2019. Weed management in direct-seeded rice systems: Implications for crop productivity. *Crop Protection*. 120: 39-48. https://doi.org/10.1016/j.cropro.2019.02.012

Chauhan, B.S. and Mahajan, G. 2021. Direct-seeded rice: Principles, practices, and prospects. *Advances in Agronomy*, 166: 1-48. https://doi.org/10.1016/bs.agron.2020.10.003

Choudhary, V.K. 2025. Seed rate & weed management on dry direct-seeded rice. *Crop Protection*.

Das, P., Mandal, B., Murmu, K. and Sarkar, A. 2023. Weed dynamics and productivity of transplanted aromatic rice as influenced by pre-and post-emergence herbicides in lower Gangetic alluvial zone.

Dharshini, K.A., Sudhakar, P., Manimaran, S. and Venkatakrishnan, D. 2025. Characterizing the influence of zinc, iron and silicon on growth dynamics and yield optimization in transplanted rice. *Ecology, Environment & Conservation*. 31: 1-8.

Gaines, T.A., Duke, S.O., Morran, S., Rigon, C.A., Tranel, P.J., Küpper, A. and Dayan, F.E. 2020. Mechanisms of evolved herbicide resistance. *Journal of Biological*

Chemistry. 295(30): 10307-10330

Gogoi, A.K., Deka, S. and Das, T.K. 2022. Herbicide resistance in rice ecosystems: Status, causes, and management options. *Pest Management Science*. 78(8): 3375-3386. https://doi.org/10.1002/ps.6992

Islam, A.M., Said, M.A., Rhaman, M., Jahan, I., Yeasmin, S., Hasan, M. and Anwar, M.P. 2024. Weed Response to Different Tank-Mix Herbicide Combinations and its Impact on Winter Rice Performance in Zero Till Non-Puddled Condition. *Fundamental and Applied Agriculture*. 9(3): 220-231.

Jehangir, I.A., Bhat, M.A. and Mir, S.A. 2024. Effect of early post-emergence herbicides on weed control efficiency and yield of direct-seeded rice. *Indian Journal of Agronomy*. 69(1): 89-95.

Kalaiarasanvenkatesan, E., Elankavi, S., Sudhakar, P. and Elango, R. 2024. Influence of different agronomic strategies on growth and yield of rice. *Journal of Applied Agronomy*. 16(1): 45–52.

Karthickraja, M., Sudhakar, P., Ramesh, S. and Kumar, B.S. 2022. Evaluation of rice varieties for growth and yield performance in aerobic cultivation. *International Journal of Plant & Soil Science*. 34: 532-538.

Kaur, R., Singh, G. and Brar, A.S. 2025. Economic and environmental benefits of new-generation herbicides in direct-seeded rice. *Journal of Environmental Biology. 46*(1): 112-118.

Kaur, R., Singh, S. and Gill, G. 2023. Performance of new-generation herbicides in direct-seeded rice. *Indian Journal of Weed Science*. 55(4): 341-348.

Kaur, S., Sandhu, K.S. and Singh, M. 2025. Low-dose herbicide strategies for sustainable weed management in direct-seeded rice. *Agronomy*. 15(2): 214.

Kokilam, M.V., Thiyagarajan, T. M. and Balasubramanian, T.N. 2016. Weed dynamics and productivity of direct wet seeded rice. *Indian Journal of Agricultural Research.* 50(4): 345-350.

Kumar, V., Singh, S. and Choudhary, V.K. 2020. Weed management challenges and opportunities in direct-seeded rice. *Crop Protection*. 138: 105311. https://doi.org/10.1016/j.cropro.2020.105311

Mahajan, G., Chauhan, B.S. and Timsina, J. 2020. Weed biology and management in rice-based cropping systems. *Agronomy*. 10(3): 385. https://doi.org/10.3390/agronomy10030385

Menon, M.V., Babu, A. and Sreelatha, N. 2019. Herbicide mixtures for weed management in wet-seeded rice. *Indian Journal of Weed Science.* 51(3): 295-297.

Nayak, S.C., Mishra, J.S., Singh, V.P. and Rao, A.N. 2018. Pretilachlor + pyrazosulfuron-ethyl (ready-mix) against complex weed flora in transplanted rice. *Indian Journal of Weed Science.* 50(3): 257-261.

Parthipan, T., Subramaniyan, K. and Kalpana, R. 2013. Integrated weed management practices on growth and yield of direct-seeded lowland rice. *Indian Journal of Weed Science.* 45(1): 7-11.

Premnath, K., Suseendran, K., Kalaiyarasan, C. and Jawahar, S. 2024. Effect of integrated weed management practices in rice (*Oryza sativa*) Under SRI. *Journal of Scientific Research and Reports*. 30(10): 22-27.

Rao, A.N., Wani, S.P., Ramesha, M.S. and Ladha, J. K. 2021. Weeds and weed management of rice in Asia. *Weed Science.* 69(6): 567-582. https://doi.org/10.1017/wsc.2021.41

Rastogi, M., Dhyani, B.P., Kumar, M., Singh, A. and Verma, S. 2024. The impact of integrated weed management practices on nutrient uptake in rice (*Oryza sativa* L.). *Journal of Scientific Research.* 30(10): 169-176.

Yadav, D.B., Yadav, A., Punia, S.S., Singh, N. and Duhan, A. 2018. Pretilachlor+ pyrazosulfuron-ethyl (ready-mix) against complex weed flora in transplanted rice and its residual effects.

Sen, S., Rao, A.N., Mishra, J.S. and Singh, V.P. 2020. Weed management in dry direct-seeded rice. *Indian Journal of Weed Science.* 52(2): 169-174.

Singh, M., Yadav, R.S. and Kumar, S. 2022. Weed dynamics and crop–weed competition in direct-seeded rice. *Indian Journal of Weed Science*. 54(3): 210-216.

Singh, R. and Sharma, S. 2022. Weed dynamics and control in DSR systems. *Indian Journal of Agronomy.* 67(1): 112-120.

Singh, V.P., Yaduraju, N.T. and Mishra, J.S. 2021. Factors influencing the efficacy of herbicides in direct-seeded rice. *Indian Journal of Agronomy*. 66(3): 307-313.

Teja, M., Sudhakar, P., Manimaran, S. and Parthasarathi, R. 2024. Standardizing foliar application of nano nutrients to augment rice (*Oryza sativa* L.) productivity. *Indian Journal of Applied & Pure Biology*. 39(2): 889-895.

Tomar, S.S., Singh, A.K. and Meena, R.K. 2019. Effect of hand weeding and herbicides on weed control efficiency in rice. *Indian Journal of Agricultural Sciences. 89*(9): 1472-1476.

Tripathi, S.C., Singh, R.K. and Mishra, J.S. 2023. Integrated weed management strategies for enhancing productivity of direct-seeded rice. *Field Crops Research*. 295: 108874. https://doi.org/10.1016/j.fcr.2023.108874

Yadav, D.B., Yadav, A., Punia, S.S., Singh, N. and Duhan, A. 2018. Pretilachlor+ pyrazosulfuron-ethyl (ready-mix) against complex weed flora in transplanted rice and its residual effects.