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Sequential pre- and post-emergence herbicide premixes for weed management in dry direct-seeded rice in the mid-hills of Himachal Pradesh, India

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ABSTRACT

Weeds are the most serious biotic constraint in dry direct-seeded rice (DSR), where they emerge with the crop and no standing water is available to suppress them. A field experiment was conducted in the kharif season of 2024 at the Experimental Farm of the Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, to evaluate ready-mix (RM) and tank-mix (TM) herbicide products in dry DSR (cv. HPR-2656, Him Palam Dhan-1). Twelve treatments were compared: six pre-emergence (PE) followed by (fb) post-emergence (PoE) herbicide sequences, two sole PoE premixes, two herbicide sequences supplemented with one hand weeding (HW) at 60 days after sowing (DAS), a weed free check and a partially weedy check. Pendimethalin + pyrazosulfuron-ethyl (RM) at 785 g/ha fb florypyrauxifen-benzyl + cyhalofop-butyl (RM) at 150 g/ha (T1) gave the lowest weed density and dry weight among the herbicide treatments up to 60 DAS (14.54 g/m² of weed dry weight at 60 DAS against 117.04 g/m² in the partially weedy check), with weed control efficiency (WCE) of 93.17, 93.75 and 87.58% at 20, 40 and 60 DAS. The grain yield with this treatment (3.25 t/ha) was at par with the weed free check (3.43 t/ha) and 139% higher than that of the partially weedy check (1.36 t/ha); the weed index was 5.25%. Pendimethalin or pretilachlor fb bispyribac-sodium + 1 HW at 60 DAS gave the best late-season control (WCE 80.20–84.15% at harvest) but yielded only 2.52–2.63 t/ha because weeds competed with the crop until 60 DAS. Sole PoE applications at 20 DAS were inadequate (weed index 31–34%). Across treatments, weed dry weight at 60 DAS explained 93% of the variation in grain yield ($r = -0.966$). A PE pre-mix followed by a broad-spectrum PoE pre-mix is a promising option for dry DSR under mid-hill conditions; the findings need confirmation over more seasons.

Keywords: Dry direct-seeded rice, Weed management, Pre-emergence herbicides, Post-emergence herbicides, Weed control efficiency

1. Introduction

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population, and it is commonly grown by transplanting seedlings into puddled soil, a system that is labour-, water- and energy-intensive and is becoming less profitable as these resources become scarce (Kumar *et al.*, 2011) [1]. Direct seeding has therefore attracted growing interest; published comparisons show that it can give yields similar to puddled transplanting with savings in irrigation water, labour and production cost (Kumar *et al.*, 2011) [1].

Weeds are, however, the main biological constraint to DSR. Aerobic rice systems face much higher weed pressure than puddled transplanted rice (Rao *et al.*, 2007) [2] because the crop and weeds are of similar size at emergence and there is no suppressive effect of standing water at establishment (Chauhan, 2012) [3]. Where weeds were not controlled, yield losses in DSR of 59.0–65.6% in eastern India (Mondal *et al.*, 2019) [4] and 68.7% in north-west India (Kaur *et al.*, 2023) [5] have been reported. Hand weeding is effective but is increasingly limited by labour availability at critical times and by cost, as noted for Himachal Pradesh, where rice productivity has been reported to be well below the national average (Rana *et al.*, 2018) [6]. Herbicides have therefore become the backbone of weed management in DSR.

No single herbicide controls the diverse weed flora of DSR, and continuous use of the same molecules has been associated with a shift from annual grasses towards broad-leaved weeds and sedges (Kaur *et al.*, 2023) [5]; a shift towards hard-to-control weeds and the evolution of herbicide resistance are recognised risks of the move to DSR (Kumar *et al.*, 2011) [1]. Pre-emergence herbicides such as pendimethalin provide effective control only during the first 20–25 days, and later-emerging weeds need a post-emergence application, so that sequential pre- followed by post-emergence programmes are considered necessary for broad-spectrum control during the critical period (Verma *et al.*, 2025) [7]. Ready-mix formulations combining molecules with different spectra and modes of action can widen the range of weeds controlled and have outperformed sole herbicides in DSR (Mondal *et al.*, 2019) [4]. Pendimethalin + pyrazosulfuron-ethyl (Kaur *et al.*, 2023) [5] and penoxsulam + pendimethalin (Kaur *et al.*, 2025) [8] have been evaluated as PE premixes in DSR, and flor

pyrauxifen-benzyl + cyhalofop-butyl as a PoE premix in dry- and wet-seeded rice (Kaur *et al.*, 2025; Mahapatra *et al.*, 2023) [9, 10]. To our knowledge, information on how these premixes perform when used in sequence with each other, relative to programmes supplemented with hand weeding, is limited for dry DSR in the mid-hills of Himachal Pradesh.

The present study was therefore undertaken to evaluate the effect of sequential ready-mix and tank-mix herbicide combinations for weed control, weed control efficiency and grain yield in dry direct seeded rice under mid-hill conditions.

2. Materials and Methods

2.1. Experimental site and soil

The experiment was conducted during the kharif season of 2024 at the Experimental Farm, Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India (32°6' N latitude, 76°3' E longitude, 1290.8 m above mean sea level),

which lies in the North-Western Himalayan region. Seasonal rainfall totalled 2481.5 mm. The soil of the experimental field was silty clay loam and acidic in reaction (pH 5.28), with 0.54% organic carbon and available N, P and K of 248.60, 23.65 and 301.30 kg/ha, respectively.

2.2. Experimental design and treatments

The experiment was laid out in a randomised block design with 12 treatments and three replications; the gross plot size was 12.88 m². The treatments comprised herbicide sequences based on ready-mix and tank-mix products, two herbicide sequences supplemented with one hand weeding, a weed-free check and a partially weedy check (Table 1). In the sequential treatments, the pre-emergence (PE) herbicide was applied at 3 DAS and the post-emergence (PoE) herbicide at 20 DAS. After weed observations were taken at 60 DAS, weeds were removed by hand weeding in T9 and T10 and cut down in T12. Herbicides were applied with a power knapsack sprayer in 500 L/ha of water. The weed-free check (T11) was kept weed free by hand weeding at 20-day intervals.

Table 1. Details of weed control treatments.

No.	Treatment	Dose (g/ha)	Time of application
T ₁	Pendimethalin + pyrazosulfuron-ethyl (RM) <i>fb</i> florpyrauxifen-benzyl + cyhalofop-butyl (RM)	785 <i>fb</i> 150	PE <i>fb</i> PoE at 20 DAS
T ₂	Pretilachlor + pyrazosulfuron-ethyl (RM) <i>fb</i> florpyrauxifen-benzyl + cyhalofop-butyl (RM)	615 <i>fb</i> 150	PE <i>fb</i> PoE at 20 DAS
T ₃	Pyrazosulfuron-ethyl <i>fb</i> florpyrauxifen-benzyl + cyhalofop-butyl (RM)	22.5 <i>fb</i> 150	PE <i>fb</i> PoE at 20 DAS
T ₄	Pendimethalin + pyrazosulfuron-ethyl (RM) <i>fb</i> bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl (RM)	785 <i>fb</i> 43	PE <i>fb</i> PoE at 20 DAS
T ₅	Penoxsulam + pendimethalin (RM) <i>fb</i> fenoxaprop + ethoxysulfuron (TM)	625 <i>fb</i> 67 + 18	PE <i>fb</i> PoE at 20 DAS
T ₆	Florpyrauxifen-benzyl + cyhalofop-butyl (RM)	150	PoE at 20 DAS
T ₇	Bispyribac-sodium + chlorimuron-ethyl + metsulfuron-methyl (RM)	43	PoE at 20 DAS
T ₈	Penoxsulam + butachlor (RM) <i>fb</i> fenoxaprop + ethoxysulfuron (TM)	820 <i>fb</i> 67 + 18	PE <i>fb</i> PoE at 20 DAS
T ₉	Pendimethalin <i>fb</i> bispyribac-sodium + 1 HW at 60 DAS	1000 <i>fb</i> 25	PE <i>fb</i> PoE at 20 DAS; HW at 60 DAS
T ₁₀	Pretilachlor <i>fb</i> bispyribac-sodium + 1 HW at 60 DAS	800 <i>fb</i> 25	PE <i>fb</i> PoE at 20 DAS; HW at 60 DAS
T ₁₁	Weed free	—	Hand weeding
T ₁₂	Partially weedy check	—	Weeds cut down at 60 DAS

RM = ready-mix; TM = tank-mix; *fb* = followed by; PE = pre-emergence; PoE = post-emergence; HW = hand weeding; DAS = days after sowing.

2.3. Crop management

Rice cultivar HPR-2656 (Him Palam Dhan-1) was direct-seeded in dry soil on 18 June 2024 at a seed rate of 100 kg/ha in rows 20 cm apart. A fertilizer dose of 60:30:30 kg N:P₂O₅:K₂O/ha was applied through urea, single super phosphate and muriate of potash as nutrient source. All other agronomic practices followed the standard package of practices for the region.

2.4. Observations

Total weed count and weed dry weight were recorded at 20, 40, 60, 80 and 100 DAS and at harvest from two quadrats of 0.5 m × 0.5 m placed randomly in each plot. Weed samples were oven-dried at 70 °C until constant weight. Grain yield was recorded from the net plot, adjusted to 14% moisture and expressed in t/ha. Harvest index (HI) was computed as the ratio of grain yield to total biological yield, expressed as a percentage. Weed control efficiency (WCE) on a dry-weight basis (Mani *et al.*, 1973) [11] and weed index (WI) (Gill *et al.*, 1969) [12] were calculated as:

$$\text{WCE (\%)} = [(W_{Dc} - W_{Dt}) / W_{Dc}] \times 100$$

$$\text{WI (\%)} = [(Y_w - Y_t) / Y_w] \times 100$$

where W_{Dc} and W_{Dt} are the weed dry weights in the partially weedy check and the treated plot, and Y_w and Y_t are the grain yields in the weed-free and treated plots, respectively. The increase in grain yield over the partially weedy check was also calculated.

2.5. Statistical analysis

Data were analysed by analysis of variance appropriate to the design (Gomez *et al.*, 1984) [13]. Weed count and weed dry weight data were transformed by the square-root transformation $\sqrt{x+1}$ before analysis, and treatment means were compared using the critical difference (CD) at $P = 0.05$; values in parentheses in the tables are original means. The data are from a single season (2024), so treatment × season interaction could not be tested. The relationship between weed dry weight at 60 DAS and grain yield across the 12 treatment means was examined by simple correlation and linear regression.

3. Results

3.1 Effect of weed control treatments on weed density

The data on total weed count (no./m²) as influenced by different weed control treatments at periodic intervals are presented in Table 2.

The data revealed that weed density was significantly influenced by the weed control treatments at all stages of observation. The partially weedy check (T₁₂) recorded the significantly highest weed density, increasing progressively through the early and mid-growth stages to a peak at 60 DAS, thereafter declining following the cutting down of weeds at that stage, and remaining moderately high through to harvest. The weed free check (T₁₁) remained free of weeds throughout the crop growth period.

Among the herbicide treatments, pendimethalin + pyrazosulfuron-ethyl *fb* florypyrauxifen-benzyl + cyhalofop-butyl at 785 *fb* 150 g/ha (T₁) recorded the significantly lowest weed density at 20, 40 and 60 DAS, remaining statistically at par with the other pre-emergence (PE) *fb* post-emergence (PoE) premix sequences, namely pretilachlor + pyrazosulfuron-ethyl (RM) *fb* florypyrauxifen-benzyl + cyhalofop-butyl (RM) at 615 *fb* 150 g/ha (T₂), pendimethalin + pyrazosulfuron-ethyl (RM) *fb* bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl (RM) at 785 *fb* 43 g/ha (T₄), penoxsulam + pendimethalin (RM) *fb* fenoxaprop + ethoxysulfuron (TM) at 625 *fb* 67 + 18 g/ha (T₅) and penoxsulam + butachlor (RM) *fb* fenoxaprop + ethoxysulfuron (TM) at 820 *fb* 67 + 18 g/ha (T₈), at all three stages

and was significantly superior to pyrazosulfuron-ethyl *fb* florypyrauxifen-benzyl + cyhalofop-butyl (RM) at 22.5 *fb* 150 g/ha (T₃), florypyrauxifen-benzyl + cyhalofop-butyl (RM) at 150 g/ha (T₆), bispyribac-sodium + chlorimuron-ethyl + metsulfuron-methyl (RM) at 43 g/ha (T₇), pendimethalin *fb* bispyribac-sodium along with one hand weeding at 60 DAS at 1000 *fb* 25 g/ha (T₉), and pretilachlor *fb* bispyribac-sodium along with one hand weeding at 60 DAS at 800 *fb* 25 g/ha (T₁₀). Treatments T₆ and T₇, comprising sole PoE herbicides, were statistically at par with the partially weedy check at 20 DAS, since these products had not yet been applied; they did, however, achieve a marked reduction in weed density relative to the check by 40 DAS.

3.2 Effect of weed control treatments on weed dry weight

The data on total weed dry weight (g/m²) as influenced by different weed control treatments at periodic intervals are presented in Table 3 and Figure 1.

The partially weedy check recorded the significantly highest weed dry weight, peaking at 60 DAS and remaining high thereafter, while the weed free check recorded no weed biomass at any stage.

Among the herbicide-only treatments, T₁ recorded the significantly lowest weed dry weight up to 60 DAS, representing a substantial reduction over the check at this stage. At 20 to 60 DAS, T₁ was statistically at par with T₂, T₄, T₅ and T₈, and significantly lower than T₃, T₆, T₇, T₉ and T₁₀.

Table 2. Effect of weed control treatments on total weed count (no./m²) at periodic intervals

Treatment	20 DAS	40 DAS	60 DAS
T ₁	3.79 (14.67)	5.83 (33.33)	7.47 (56.00)
T ₂	6.25 (38.67)	8.03 (64.00)	10.04 (100.00)
T ₃	8.63 (77.33)	11.48 (133.33)	13.88 (196.00)
T ₄	5.28 (28.00)	7.21 (52.00)	9.75 (94.67)
T ₅	5.33 (28.00)	7.48 (56.00)	9.56 (90.67)
T ₆	13.81 (190.67)	11.46 (130.67)	13.35 (178.67)
T ₇	13.68 (190.67)	9.65 (94.67)	12.90 (166.67)
T ₈	5.47 (30.67)	7.43 (54.67)	9.26 (85.33)
T ₉	7.54 (57.33)	10.43 (110.67)	11.87 (146.67)
T ₁₀	6.93 (48.00)	10.11 (101.33)	12.13 (148.00)
T ₁₁	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T ₁₂	14.06 (200.00)	18.94 (361.33)	23.02 (532.00)
SEm ±	0.85	0.81	0.90
CD (P = 0.05)	2.50	2.38	2.65

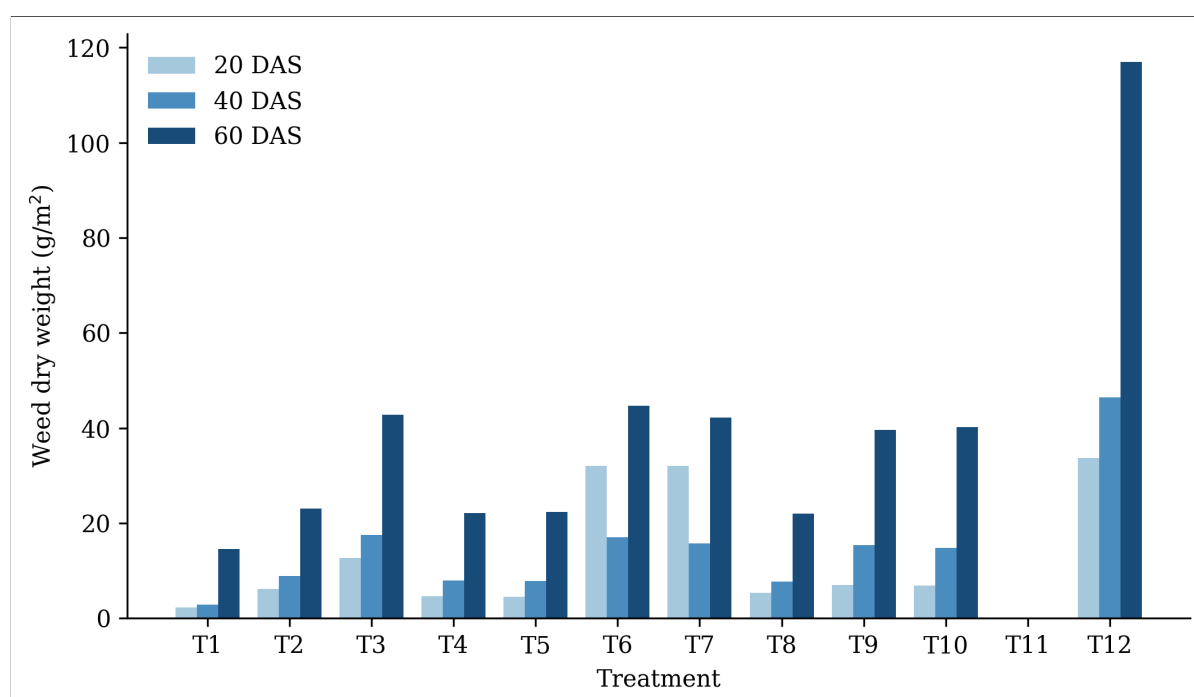
Values are $\sqrt{(x + 1)}$ transformed; original means in parentheses.

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Table 3. Effect of weed control treatments on total weed dry weight (g/m^2) at periodic intervals.

Treatment	20 DAS	40 DAS	60 DAS
T ₁	1.77 (2.30)	1.94 (2.90)	3.92 (14.54)
T ₂	2.68 (6.19)	3.13 (8.92)	4.90 (23.05)
T ₃	3.53 (12.70)	4.13 (17.50)	6.61 (42.73)
T ₄	2.34 (4.61)	2.97 (7.88)	4.79 (22.11)
T ₅	2.31 (4.49)	2.96 (7.82)	4.82 (22.37)
T ₆	5.71 (32.02)	4.15 (17.02)	6.76 (44.73)
T ₇	5.74 (32.04)	4.09 (15.77)	6.55 (42.16)
T ₈	2.51 (5.32)	2.95 (7.69)	4.79 (22.05)
T ₉	2.82 (7.01)	4.04 (15.32)	6.37 (39.57)
T ₁₀	2.80 (6.93)	3.98 (14.84)	6.37 (40.20)
T ₁₁	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T ₁₂	5.85 (33.71)	6.79 (46.42)	10.79 (117.04)
SEm $\pm$	0.34	0.43	0.36
CD ($P = 0.05$)	0.99	1.25	1.05

Values are $\sqrt{(x + 1)}$ transformed; original means in parentheses.

**Figure 1.** Weed dry weight (g/m^2) under different weed control treatments at 20, 40 and 60 DAS.

3.3. Weed control efficiency

Data presented in Table 4 revealed that weed control efficiency varied among treatments. At 20 DAS, the highest weed control efficiency among herbicidal treatments was recorded with T₁, followed by T₅, T₄ and T₈, whereas T₆ and T₇ recorded the lowest. At 40 and 60 DAS, T₁ maintained the highest weed control efficiency, followed by T₈, T₅ and T₄, while T₃, T₆ and T₇ recorded comparatively lower effi-

ciency. The weed-free treatment (T₁₁) recorded 100 per cent efficiency, whereas the partially weedy check (T₁₂) recorded zero efficiency at all stages.

T₁ recorded the significantly highest WCE up to 60 DAS (93.17, 93.75 and 87.58% at 20, 40 and 60 DAS, respectively), followed by and statistically at par with the other PE *fb* PoE premix sequences T₂, T₄, T₅ and T₈ (80.3–86.7% across these stages).

Table 4. Effect of weed control treatments on weed control efficiency (%) at periodic intervals

Treatment	20 DAS	40 DAS	60 DAS
T ₁	93.17	93.75	87.58
T ₂	81.63	80.79	80.31
T ₃	62.33	62.29	63.49
T ₄	86.33	83.03	81.11
T ₅	86.67	83.16	80.88
T ₆	5.02	63.33	61.78
T ₇	4.96	66.04	63.98
T ₈	84.22	83.43	81.16
T ₉	79.21	67.00	66.19
T ₁₀	79.44	68.03	65.65
T ₁₁	100.00	100.00	100.00
T ₁₂	0.00	0.00	0.00

WCE calculated on a dry-weight basis relative to the partially weedy check (T₁₂).

3.4. Grain yield, weed index and harvest index

The data on grain yield, weed index and harvest index are presented in Table 5 and Figure 2.

Grain yield differed significantly among treatments. The weed free check recorded the significantly highest yield (3.43 t/ha) and the partially weedy check the significantly lowest (1.36 t/ha), a yield reduction of 60.35 per cent. Among the herbicide treatments, T₁ recorded the highest yield (3.25 t/ha), which was statistically at par with the weed free check and with T₅, T₈, T₄ and T₂ (3.12, 3.06, 3.04 and 2.96 t/ha, respectively), and represented a 139 per cent increase over the partially weedy check. T₁ also recorded the lowest weed index

(5.25%) among all the herbicide treatments. The yield of T₂ (2.96 t/ha) was, however, significantly lower than that of the weed free check, whereas T₁, T₅, T₈ and T₄ were statistically at par with it.

T₉ and T₁₀ (2.63 and 2.52 t/ha; weed index 23.32 and 26.53%, respectively), despite recording the highest late-season WCE, yielded significantly less than T₁, T₅, T₈ and T₄, their weed density and dry weight at 60 DAS being about 2.6 and 2.7–2.8 times higher, respectively, than in T₁. T₃, T₆ and T₇ also yielded significantly less than T₁, T₅, T₈ and T₄ (2.50, 2.28 and 2.36 t/ha; weed index 27.11, 33.53 and 31.20%, respectively). Harvest index ranged narrowly from 35.30 to 37.25 per cent and did not differ significantly among the treatments.

Table 5. Effect of weed control treatments on grain yield, weed index and harvest index of rice.

Treatment	Grain yield (t/ha)	Increase over partially weedy check (%)	Weed index (%)	Harvest index (%)
T ₁	3.25	139.0	5.25	36.96
T ₂	2.96	117.6	13.70	36.32
T ₃	2.50	83.8	27.11	35.85
T ₄	3.04	123.5	11.37	36.40
T ₅	3.12	129.4	9.04	36.71
T ₆	2.28	67.6	33.53	35.88
T ₇	2.36	73.5	31.20	36.19
T ₈	3.06	125.0	10.79	36.74
T ₉	2.63	93.4	23.32	36.03
T ₁₀	2.52	85.3	26.53	35.99
T ₁₁	3.43	152.2	0.00	37.25
T ₁₂	1.36	0.0	60.35	35.30
SEm ±	0.14	—	—	0.46
CD (P = 0.05)	0.40	—	—	NS

Weed index calculated from grain yield with T₁₁ (weed free) as reference; increase over T₁₂ (partially weedy check) calculated from mean grain yield. NS = not significant.

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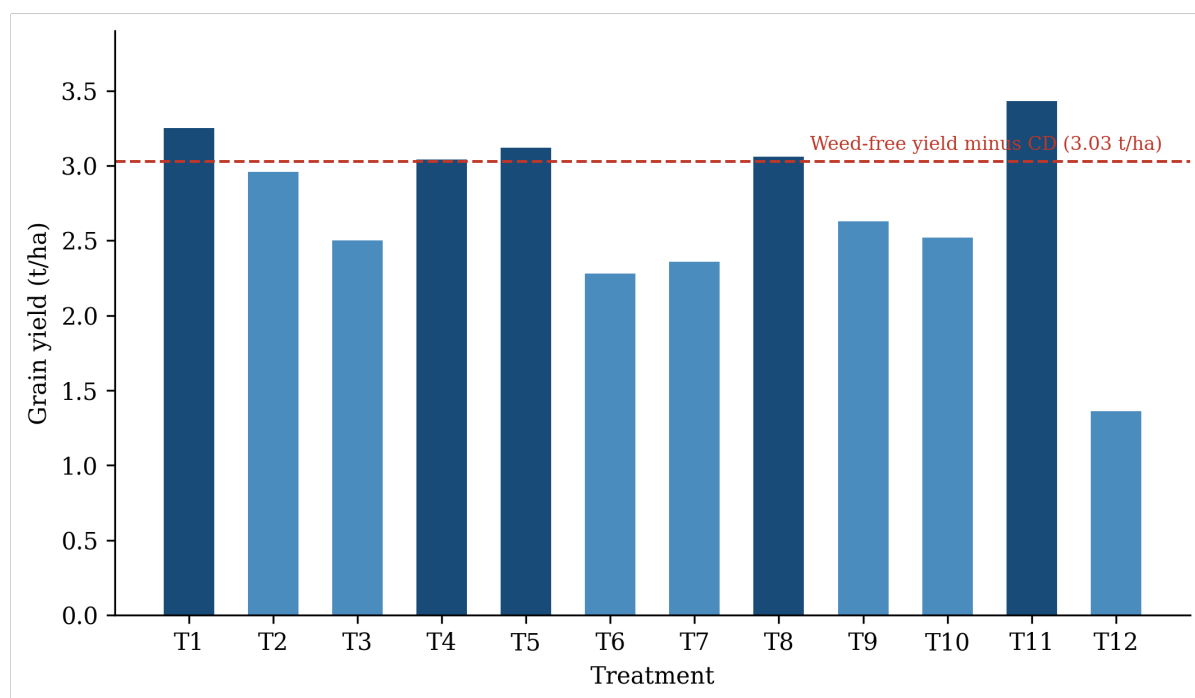


Figure 2. Grain yield of dry direct-seeded rice under different weed control treatments. The dashed line marks the weed-free yield minus the CD (0.40 t/ha); treatments above it are at par with the weed-free check..

3.5. Relationship between weed growth and grain yield

Across the 12 treatment means, grain yield was strongly and negatively related to weed dry weight at 60 DAS ($r = -0.966$; $y = 3.38 - 0.0188x$; $R^2 = 0.93$; Figure 3); each additional 10 g/m² of weed dry

weight at 60 DAS was associated with a yield reduction of about 0.19 t/ha. The correlation with weed count at 60 DAS was $r = -0.948$. Correlations of yield with weed dry weight were equally strong at 40 DAS ($r = -0.967$) but weaker at 80 DAS ($r = -0.626$), 100 DAS ($r = -0.762$) and harvest ($r = -0.827$).

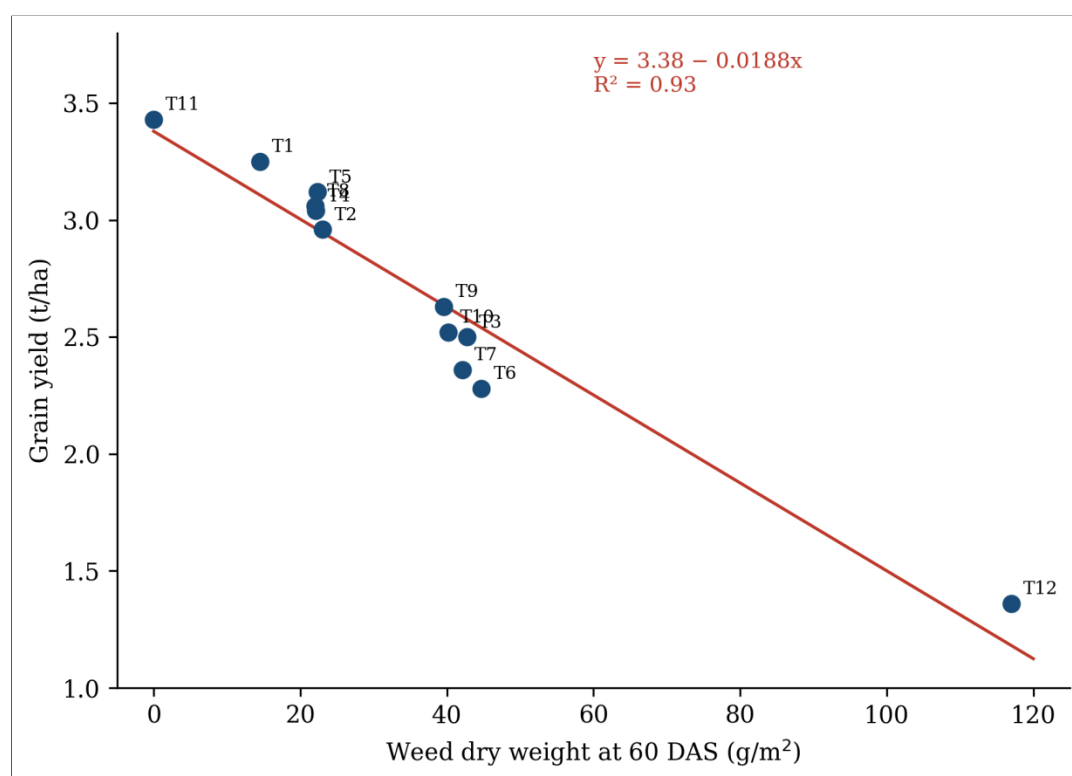


Figure 3. Relationship between weed dry weight at 60 DAS and grain yield of rice ($n = 12$ treatment means).

4. Discussion

4.1 Weed density and weed dry weight

The significantly lower weed density and dry weight under the PE *fb* PoE premix sequences reflect the complementary action of a pre-emergence herbicide, active mainly during the first 20–25 days

(Verma *et al.*, 2025) [7], combined with a broad-spectrum post-emergence partner controlling later weed flushes. The parity of T₁ with T₂, T₄, T₅ and T₈ across all three stages confirms these premix combinations were similarly effective, consistent with reports that ready-mix combinations outperform sole herbicide applications in direct-seeded rice (Mondal *et al.*, 2019; Kaur *et al.*, 2023) [4, 5].

The parity of T₆ and T₇ with the check at 20 DAS simply reflects these sole post-emergence products not yet being applied; their sharp decline in both count and dry weight by 40 DAS marks the onset of herbicidal action (Verma *et al.*, 2025) [7].

Overall, the closely matching trends in weed count and dry weight confirm that a sequential PE *fb* PoE programme sustains weed suppression more effectively across the season than either a single herbicide application or a late hand weeding alone.

4.3 Weed control efficiency

The higher weed control efficiency recorded with T₁ throughout the observation period may be attributed to the sequential application of pendimethalin + pyrazosulfuron-ethyl as a pre-emergence mixture followed by florypyrauxifen-benzyl + cyhalofop-butyl as a post-emergence mixture. The pre-emergence application provided effective early-season suppression of emerging weeds, while the subsequent post-emergence application controlled the escaped and newly emerged weed flora, resulting in sustained weed suppression. The comparatively lower weed control efficiency of T₆ and T₇, particularly at the early stage, may be due to their post-emergence application, which allowed weeds to emerge before herbicide application. The relatively higher efficiency of T₄, T₅ and T₈ may be attributed to their sequential or broad-spectrum herbicide combinations, which provided effective control of diverse weed species. The 100 per cent weed control efficiency under T₁₁ was due to continuous maintenance of weed-free conditions, whereas zero efficiency in T₁₂ was expected because it represented the untreated partially weedy condition.

4.4 Grain yield, weed index and harvest index

The grain yield of T₁, being statistically at par with the weed free check, together with its low weed index, corroborates its superior and sustained weed suppression through the critical early period, and is consistent with reports that sequential pre- followed by post-emergence herbicide programmes are among the most effective options for protecting yield in dry-seeded rice (Mahajan *et al.*, 2013; Kaur *et al.*, 2015; Pinjari *et al.*, 2016) [14, 15, 16]. The significantly lower yield of T₉ and T₁₀, despite their high late-season WCE, is explained by the substantially greater weed density and dry weight these treatments carried at 60 DAS relative to T₁ - indicating that yield had already been compromised by early-season weed competition before hand weeding was carried out, and that late-season control, however effective, could not fully recover the yield potential lost earlier. This finding underscores the importance of weed suppression specifically within the first 60 days, corresponding to the critical period of crop-weed competition in dry DSR (Verma *et al.*, 2025) [7], over cumulative control achieved by the end of the season. The significantly lower yield of T₃, T₆ and T₇ likewise reflects their comparatively poor early-season control. The absence of a significant effect of the weed control treatments on harvest index indicates that the yield losses observed were primarily a consequence of reduced overall crop growth and biomass accumulation under weed competition, rather than any alteration in the partitioning of dry matter between grain and straw.

4.4. Practical implications and limitations

Within the treatments tested, T₁ gave the best combination of early weed suppression and grain yield, with T₅, T₈ and T₄ statistically at par with it for yield and offering alternative modes of action, which is relevant because rotation of modes of action helps limit weed shifts and herbicide resistance (Kumar *et al.*, 2011; Kaur *et al.*, 2023) [1, 5]. The study has limitations: it covers a single season (2024); weed flora composition was not recorded here; the economics of the treatments and possible crop phytotoxicity were not evaluated; and the check was cut at 60 DAS, which restricts comparisons at later stages. The findings should therefore be confirmed over more seasons, together with a cost analysis, before a firm recommendation is made.

5. Conclusions

In this single-season study of dry direct-seeded rice in the mid-hills of Himachal Pradesh, pendimethalin + pyrazosulfuron-ethyl (RM) at 785 g/ha as pre-emergence, followed by florypyrauxifen-benzyl + cyhalofop-butyl (RM) at 150 g/ha at 20 DAS, gave the lowest early weed density and dry weight among the herbicide treatments, the highest weed control efficiency up to 60 DAS (up to 93.75%) and a grain yield (3.25 t/ha) at par with the weed-free check, with a weed index of 5.25%. Sequences of pendimethalin or pretilachlor *fb* bispyribac-sodium with hand weeding at 60 DAS controlled late weeds best but lost yield to early competition, and sole post-emergence applications at 20 DAS were inadequate. Weed dry weight at 60 DAS explained 93% of the variation in grain yield. Effective weed control in the first 60 days, using a pre-emergence premix followed by a broad-spectrum post-emergence premix, is therefore the key to high yield in dry DSR, and the alternative sequences T₅, T₈ and T₄, which were at par with T₁ for yield, may serve for herbicide rotation.

Data Availability The data supporting the findings of this study are included within the article and are available from the corresponding author upon reasonable request

Conflicts of Interest The authors declare that there are no conflicts of interest regarding the publication of this paper

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Authors' Contributions Shivalika conceived and designed the study, conducted the field experiment, collected and analysed the data, and drafted the manuscript. G.D. Sharma supervised the research, contributed to the experimental design, and reviewed and edited the manuscript. Sandeep Manuja assisted with the statistical analysis and contributed to manuscript revision. N.K. Sankhyani provided overall guidance, contributed to the interpretation of results, and critically reviewed the manuscript. All authors read and approved the final manuscript.

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References

1. Kumar V, Ladha JK. Direct Seeding of Rice: Recent Developments and Future Research Needs. *Advances in Agronomy*. 2011;111:297–413.
2. Rao AN, Johnson DE, Sivaprasad B *et al.* Weed Management in Direct-Seeded Rice. *Advances in Agronomy*. 2007;93:153–255.
3. Chauhan BS. Weed Ecology and Weed Management Strategies for Dry-Seeded Rice in Asia. *Weed Technology*. 2012;26(1):1–13.
4. Mondal D, Ghosh A, Sen S *et al.* Effect of Herbicides and Their Combinations on Weeds and Productivity of Direct-Seeded Rice (*Oryza sativa*). *Indian Journal of Agronomy*. 2019;64(4):464–470.
5. Kaur S, Kaur T, Bhullar MS. Pendimethalin Plus Pyrazosulfuron for Pre-Emergence Control of Complex Weed Flora in Dry-Seeded Rice. *Indian Journal of Weed Science*. 2023;55(4):364–368.
6. Rana A, Rana MC, Rana SS *et al.* Weed Control by Pyrazosulfuron-Ethyl and Its Influence on Yield and Economics of Transplanted Rice. *Indian Journal of Weed Science*. 2018;50(4):309–314.

7. Verma NK, Chitale S, Tiwari N. Effect of Herbicides on Weeds and Direct-Seeded Rice Growth and Yield. *Indian Journal of Weed Science*. 2025;57(3):285–289.
8. Kaur T, Kaur S, Singh G *et al*. Weed Control in Direct-Seeded Rice with Ready Mix of Penoxsulam + Pendimethalin. *Indian Journal of Weed Science*. 2025;57(2):155–159.
9. Kaur T, Kaur S, Singh M *et al*. Effective Weed Management under Direct Seeded Rice through Use of Florpyrauxifen-Benzyl Plus Cyhalofop Butyl as Post-Emergence Herbicide in Northwestern India. *Indian Journal of Agronomy*. 2025;70(3):279–285.
10. Mahapatra A, Saha S, Munda S *et al*. Bio-Efficacy of Herbicide Mixtures on Weed Dynamics in Direct Wet-Seeded Rice. *Indian Journal of Weed Science*. 2023;55(1):18–23.
11. Mani VS, Malla ML, Gautam KC, Bhagwandas. Weed-Killing Chemicals in Potato Cultivation. *Indian Farming*. 1973;23(8):17–18.
12. Gill GS, Vijayakumar. Weed Index – A New Method for Reporting Weed Control Trials. *Indian Journal of Agronomy*. 1969;14(2):96–98.
13. Gomez KA, Gomez AA. *Statistical Procedures for Agricultural Research*. John Wiley & Sons; 1984.
14. Mahajan G, Chauhan BS. Herbicide Options for Weed Control in Dry-Seeded Aromatic Rice in India. *Weed Technology*. 2013;27(4):682–689.
15. Kaur S, Singh S. Bio-Efficacy of Different Herbicides for Weed Control in Direct-Seeded Rice. *Indian Journal of Weed Science*. 2015;47(2):106–109.
16. Pinjari SS, Gangawane SB, Mhaskar NV *et al*. Integrated Use of Herbicides to Enhance Yield and Economics of Direct-Seeded Rice. *Indian Journal of Weed Science*. 2016;48(3):279–283.
17. Singh VP, Singh SP, Bisht N *et al*. Assessment of Post-Emergence Weed Management in Direct-Seeded Rice. *Indian Journal of Weed Science*. 2017;49(3):211–215.
18. Chauhan BS, Johnson DE. Row Spacing and Weed Control Timing Affect Yield of Aerobic Rice. *Field Crops Research*. 2011;121:226–231.

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