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Performance of post emergence herbicides on weed control and yield of transplanted rice

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Abstract
A field experiment was carried out during *kharif 2024* at Student Farm, College of Agriculture, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad, to assess the efficacy of different pre- and post-emergence herbicide combinations on weed management and yield of transplanted rice. Eight treatments were compared, including herbicide mixtures, sequential applications, and manual weeding. Results indicated that the weed-free treatment (hand weeding at 20 and 40 DAT) recorded the lowest weed density and highest yields. However, herbicide-based treatments, particularly Bensulfuron methyl + Pretilachlor as PE followed by Florpyrauxifen-benzyl + Penoxsulam (T1) and Bensulfuron methyl + Pretilachlor as PE followed by Florpyrauxifen-benzyl + Cyhalofop-butyl (T2), performed on par with weed-free plots. These treatments achieved high weed control efficiency (>89%) and grain yields above 7100 kg ha^{-1}. In contrast, the unweeded control suffered severe weed infestation and the lowest yield. The findings highlight that sequential use of pre- and post-emergence herbicides offers an effective, economical, and sustainable alternative to labour-intensive manual weeding in transplanted rice.

Keywords: Rice, weed management, post-emergence herbicides, yield, weed control efficiency

Introduction
In India, rice is cultivated on about ~ 44 million hectares (M ha), producing nearly ~124 million tonnes (Mt), which accounts for 21.5% of the global rice output Choudharyand Dixit (2018) [2]. The country is currently almost self-sufficient in rice production; however, to maintain this self-sufficiency by 2050 and ensure food security for the projected population of 1.64 billion, the demand is expected to rise to 197.4 MT. Meeting this requirement poses a significant challenge, as it is achieved with minimal environmental impact and under constraints of limited land, labour, water, and agrochemical resources (Ahmad *et al*., 2021) [1]. Among the biotic factors, weeds are one of the most critical biological constraints, responsible for an estimated 37% reduction in crop yields Mishra *et al.* (2021) [6]. Worldwide, weed infestation accounts for approximately 10% loss in overall rice production (Oerke & Dehne, 2004) [9]. The diverse weed flora under transplanted conditions can cause yield reduction up to 72% (Singh *et al.*, 2004) [11]. Dhanapal *et al.* (2018) [4] reported that effective weed management can boost grain yield by up to 85%. Hence, timely and efficient weed control maximizes productivity in transplanted rice systems.

Manual weeding, though effective, has become less feasible due to escalating labor costs and shortages. Commonly used pre-emergence herbicides such as pretilachlor, butachlor, oxadiargyl, and anilofos (Sureshkumar *et al.*, 2016) [14] provide early-season weed control but are restricted by a narrow application window and limited efficacy against later-emerging weeds. Moreover, continuous reliance on these herbicides has resulted in weed shifts and resistance development. Consequently, post-emergence herbicides have gained prominence, offering broad-spectrum control at low doses, enhancing nutrient uptake and ultimately improving yield and profitability in rice cultivation. This study evaluates the efficacy, crop safety, and profitability of different post-emergence herbicides in transplanted rice.

Materials and Methods
A field experiment was carried out during *kharif 2024* at Student Farm, College of Agriculture,

Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad. The soil type was red chalk soils and neutral in nature (pH 7.42), having an EC of 0.36 dS m-1, organic carbon (0.23 %), available nitrogen (277.20 kg ha-1), phosphorus (31.24 kg ha-1), and potassium (277.50 kg ha-1). The experiment was laid out in a randomized block design with eight treatments and replicated thrice having gross plot of 20.25 m $^{-2}$ (4.5 m × 4.5 m) area. The treatments were composed of different weed management practices *viz.*, Bensulfuron methyl 0.6%+ Pretilacholr 6% GR 60+600 g ha^{-1} as PE and Florpyrauxifen-benzyl1.31%+Penoxsulam 2.1% OD 26.2 + 42 g ha^{-1} as PoE at 20-25 DAT (T_1), Bensulfuron methyl 0.6% + Pretilacholr 6% GR 60+600g ha^{-1} as PE and Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w EC 21.3+106.4g ha^{-1} as PoE at 20-25DAT (T_2), Bensulfuronmethyl 0.6% + Pretilacholr 6% GR 60+600g ha^{-1} as PE and Quinclorac 25% SC 250 g/l w/v ha-1as PoE at 20-25 DAT (T_3), Bensulfuron methyl 0.6%+Pretilacholr 6% GR 60+600g ha^{-1} as PE and Penoxsulam 102% ww + Cyhalofop-butyl 5.1% w/w OD 135 g ha^{-1} as PoE at 20- 25 DAT (T_4), Bensulfuron methyl 0.6%+ Pretilacholr 6% GR 60+600 g ha^{-1} as PE and Triafamone 20% + Ethoxysulfuron 10% WG 45+22.5g ha^{-1} as PoE at 20-25DAT (T_5), Bensulfuron methyl 0.6%+ Pretilacholr 6% GR 60+600 g ha^{-1} as PE and hand weeding at 20-25DAT (T_6), hand weeding (weed-free) at 20 and 40 DAT (T_7), and weedy check/no weeding (T_8). The variety sown was KNM-1638 and the seed rate used was 50 kg ha^{-1}, with a spacing of 15 × 15 cm with two seedlings per hill. The fertilizers were applied as urea, single super phosphate and muriate of potash at a dose of 120:60:40 N, P_2O_5, K_2O kg ha^{-1}, respectively. All pre-emergence herbicides were applied within three days after transplanting, and post-emergence herbicides were applied at the 2-3 leaf stage of weeds. Density of weeds, viz., grasses, sedges, and broad-leaved weeds, was recorded using a 1.0 × 1.0 m (1 m^2) quadrat, and the dry weight of weeds was recorded from a 1.0 × 1.0 m (1 m^2) quadrat area by destructive sampling. Weed control efficiency (WCE) was calculated based on weed dry weight. The data on weed density and dry weight for all the categories were computed using the square root ($\sqrt{x} + 1$) transformation.

Results and Discussion

Weed Composition and Response to Treatments

The experimental field was infested with different categories of weeds. *Echinochloacolona, Echinochloa crus-galli, and Cynodondactylon* were predominant among grasses. *Cyperusdifformis, Cyperusiria,* and *Fimbristylisdichotoma* were observed in the case of sedges, while the major broad-leaved weeds included *Eclipta alba and Ammaniabaccifera*. Application of weed management treatments markedly reduced weed density and dry matter accumulation compared to the unweeded control.

Total weed density (number m⁻²)

Weed density is a critical indicator of the effectiveness of weed management practices. The lower densities recorded under weed-free and herbicide-based treatments demonstrate their superiority in suppressing weed flora compared to the weedy check. Effective reduction in weed density minimizes competition for nutrients, light, and moisture, creating a favorable environment for crop growth. Consequently, lower weed density directly contributes to improved productivity and sustainability in transplanted rice.

The total lowest weed density (number m^{-2}) 2.74 was observed in treatment T_7 Weed-free (hand weeding at 20 and 40 DAT).T_1 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha^{-1} as PE and Florpyrauxifen-benzyl 1.31% + Penoxsulam 2.1% OD @ 26.2 + 42 g ha^{-1} as PoE at 20-25 DAT) recorded weed density of 2.92, which was on par with T_7.These followed by T_2 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha^{-1} as PE and Florpyrauxifen-benzyl 2.13% + Cyhalofop-butyl 10.64% EC @ 21.3 + 106.4 g ha^{-1} as PoE at 20-25 DAT) 3.21, T_5 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha^{-1} as PE and Triafamone 20% + Ethoxysulfuron 10% WG @ 45 + 22.5 g ha^{-1} as PoE at 20-25 DAT), 3.46 and T_4 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha^{-1} as PE and Penoxsulam 10% + Cyhalofop-butyl 5.1% OD @ 135 g ha^{-1} as PoE at 20-25 DAT) 3.75. Conversely, in the T_8 (weedy check/no weeding), the maximum weed density of 12.32 was recorded.

Total lower weed density was recorded with the application of herbicidal options, and better performance was attributed to the effective suppression of weeds achieved through different modes of action of herbicides. These results were in tune with the findings of Mohapatra *et al.* (2021) [7] and Venkatesh *et al.* (2021) [16].

Total weed dry weight (g m⁻²)

Weed dry weight is a reliable measure of the cumulative effect of weed competition on crops. Significantly lower values under weed-free and post-emergence herbicide treatments indicate their effectiveness in suppressing weed growth compared to the weedy check. Reduced dry weight minimizes competition for essential resources, supporting better crop growth and yield in transplanted rice.

T_7 Weed-free (hand weeding at 20 and 40 DAT) significantly recorded lower total weed dry weight 2.56 g m^{-2}, which was on par with T_1 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha^{-1} as PE and Florpyrauxifen-benzyl 1.31% + Penoxsulam 2.1% OD @ 26.2 + 42 g ha^{-1} as PoE at 20-25 DAT) 2.64 g m^{-2} and T_2 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha^{-1} as PE and Florpyrauxifen-benzyl 2.13% + Cyhalofop-butyl 10.64% EC @ 21.3 + 106.4 g ha^{-1} as PoE at 20-25 DAT) 2.66 g m^{-2}. Followed by T_5 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha^{-1} as PE and Triafamone 20% + Ethoxysulfuron 10% WG @ 45 + 22.5 g ha^{-1} as PoE at 20-25 DAT) 3.67 g m^{-2} and T_4 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha^{-1} as PE and Penoxsulam 10% + Cyhalofop-butyl 5.1% OD @ 135 g ha^{-1} as PoE at 20-25 DAT) 3.75 g m^{-2}. Whereas, T_8 (weedy check/no weeding) recorded a higher total weed dry weight of7.58 g m^{-2}.

The post-emergence herbicide application reduces weed infestation, thereby lowering total weed dry weight. This is likely due to the effective control of weeds compared to pre-emergence application and hand weeding practices. These results were in tune with the findings of Kashid (2019) [5] and Choudhary and Dixit (2018) [2].

Weed control efficiency (%)

Weed control efficiency (WCE) is an important measure of how well different weed management practices suppress weed growth. The higher WCE values obtained with weed-free and herbicide treatments highlight their effectiveness over the untreated control. By reducing weed pressure, these treatments lower competition for nutrients, light, and moisture, ultimately creating favorable conditions for higher yield in transplanted rice.

The highest WCE 90.14% was recorded in the treatment T_7 Weed-free (hand weeding at 20 and 40 DAT) followed by T_1

(Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Florpyrauxifen-benzyl 1.31% + Penoxsulam 2.1% OD @ 26.2 + 42 g ha⁻¹ as PoE) with 89.43% and T_2 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Florpyrauxifen-benzyl 2.13% + Cyhalofop-butyl 10.64% EC @ 21.3 + 106.4 g ha⁻¹ as PoE) with 89.3% which were on par. These were followed by T_5 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR, followed by Triafamone 20% + Ethoxysulfuron 10% WG) with 77.87% and T_4 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR, followed by Penoxsulam 10% + Cyhalofop-butyl 5.1% OD) with 76.8%, which were also on par statistically. On the other hand, the treatment T_8 (Weedy check/No weeding) recorded the lowest WCE, 0%. These results agree with the findings of Deiveegan *et al.* (2017) [3] and Srinithan *et al.* (2021) [13].

Grain yield (kg ha^{-1})

Grain yield is the ultimate indicator of the effectiveness of weed management practices. Significantly higher yields under weed-free and herbicide-based treatments demonstrate the positive impact of effective weed suppression on crop performance. In contrast, the drastic yield reduction in the weedy check highlights the severe effect of unchecked weed competition on rice productivity.

The grain yield of rice varied significantly under different weed management practices. The treatment T_7, weed free (hand weeding at 20 and 40 DAT) recorded highest grain yield of 7186 kg ha⁻¹, which was statistically comparable with T_1 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Florpyrauxifen -benzyl 1.31% + Penoxsulam 2.1% OD @ 26.2 + 42 g ha⁻¹ as PoE) with grain yield of 7152 kg ha⁻¹ and T_2 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Florpyrauxifen-benzyl 2.13% + Cyhalofop-butyl 10.64% EC @ 21.3 + 106.4 g ha⁻¹ as PoE) with 7137 kg ha⁻¹. These were followed by T_5 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Triafamone 20% + Ethoxysulfuron 10% WG @ 45 + 22.5 g ha⁻¹ as PoE) with 6824 kg ha⁻¹ and T_4 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Penoxsulam 10% + Cyhalofop-butyl 5.1% OD @ 135 g ha⁻¹ as PoE) with 6759 kg ha⁻¹. Conversely, the lowest grain yield, 3198 kg ha⁻¹, was recorded in T_8 (weedy check/no weeding) owing to severe weed competition throughout the crop growth period.

Pramanik *et al.* (2020) [10], Naveen *et al.* (2023) [8], and Sree *et al.* (2024) [12] also reported that the lowest rice yield was with the unweeded control due to high weed density and biomass that adversely affected all the yield parameters.

Straw yield (kg ha^{-1})

The data on straw yield revealed that T_7 weed-free (hand weeding at 20 and 40 DAT) produced highest yield of 9296 kg ha⁻¹ which was statistically comparable with T_1 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Florpyrauxifen-benzyl 1.31% + Penoxsulam 2.1% OD @ 26.2 + 42 g ha⁻¹ as PoE) with 9270 kg ha⁻¹ and T_2 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Florpyrauxifen-benzyl 2.13% + Cyhalofop-butyl 10.64% EC @ 21.3 + 106.4 g ha⁻¹ as PoE) with 9236 kg ha⁻¹ followed by T_5 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Triafamone 20% + Ethoxysulfuron 10% WG @ 45 + 22.5 g ha⁻¹ as PoE) with 8827 kg ha⁻¹ and T_4 (Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 60 + 600 g ha⁻¹ as PE followed by Penoxsulam 10% + Cyhalofop-butyl 5.1% OD @ 135 g ha⁻¹ as PoE) with 8692 kg ha⁻¹. Conversely, T_8 (weedy check/no weeding) recoded the lower straw yield of 4454 kg ha⁻¹.

Efficient and timely weed management minimized crop-weed competition, allowing the crop to utilize available resources more effectively, which enhanced dry matter accumulation and increased straw yield. These findings are consistent with the observations of Tej *et al.* (2016) [15] and Venkatesh *et al.* (2021) [16].

Table1: Effect of weed management practices on total weed density (no m^{-2}), weed dry weight (no m^{-2}), and weed control efficiency (%) at maturity

	Treatments	Total weed Density (no.m^{-2})	Total weed dry weight (g m^{-2})	WCE (%)
T_1	Bensulfuron methyl 0.6% + Pretilacholr 6% GR 60+600 g ha^{-1} as PE and Florpyrauxifen-benzyl 1.31%+Penoxsulam2.1% OD 26.2+42g ha^{-1} as PoE at 20-25DAT	2.92 (8.50)	2.64 (5.97)	89.43
T_2	Bensulfuron methyl 0.6% + Pretilacholr 6% GR 60+600g ha^{-1} as PE and Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w EC 21.3+106.4g ha^{-1} as PoE at 20-25DAT	3.21 (10.30)	2.66 (6.10)	89.3
T_3	Bensulfuron methyl 0.6% + Pretilacholr 6% GR 60+600g ha^{-1} as PE and Quinclorac 25% SC 250 g/l w/v ha^{-1}as PoE at 20-25 DAT	5.11 (26.10)	4.10 (15.80)	72.04
T_4	Bensulfuron methyl 0.6% + Pretilacholr 6% GR 60 + 600 g ha^{-1} as PE and Penoxsulam 102% ww + Cyhalofop-buty l5.1%w/w OD 135g ha^{-1}as PoE at20- 25 DAT	3.75 (14.10)	3.75 (13.10)	76.8
T_5	Bensulfuron methyl 0.6% + Pretilacholr 6% GR 60+600 g ha^{-1} as PE and Triafamone 20% + Ethoxysulfuron10% WG 45+22.5g ha^{-1}as PoE at 20-25DAT	3.46 (12.00)	3.67 (12.50)	77.87
T_6	Bensulfuron methyl 0.6% + Pretilacholr 6% GR 60+600 g ha^{-1} as PE and hand Weeding at 20-25DAT	5.60 (31.40)	4.84 (22.43)	60.29
T_7	Weed free-Hand weeding at 20 and 40 DAT	2.74 (7.50)	2.56 (5.57)	90.14
T_8	Weedycheck (No weeding)	12.32 (151.75)	7.58 (56.49)	0
SE(m)±		0.19	0.18	
CD(P=0.05)		0.59	0.56	---

Values in the parenthesis are original and data is subjected to square root transformation ($\sqrt{x} + 1$).

Table 2: Effect of weed management practices on grain and straw yield (kg ha⁻¹)

	Treatments	Grain Yield (kg ha⁻¹)	Straw Yield (kg ha⁻¹)
T_1	Bensulfuron methyl 0.6%+ Pretilacholr 6% GR 60+600 g ha^{-1} as PE and Florpyrauxifen-benzyl 1.31% + Penoxsulam 2.1 % OD26.2 + 42 g ha^{-1} as PoE at 20-25DAT	7152.00	9270.00
T_2	Bensulfuronmethyl 0.6%+Pretilacholr 6% GR60 + 600 g ha^{-1} as PE and Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-buty l10.64% w/w EC 21.3 + 106.4g ha^{-1} as PoE at 20-25DAT	7137.33	9236.67
T_3	Bensulfuron methyl 0.6% + Pretilacholr6% GR60 + 600g ha^{-1}as PEand Quinclorac 25% SC 250 g/l w/v ha^{-1}as PoE at 20-25 DAT	6548.67	8424.00
T_4	Bensulfuron methyl 0.6% + Pretilacholr 6% GR 60+600 g ha^{-1} as PE and Penoxsulam 102%ww+Cyhalofop-butyl 5.1%w/w OD 135g ha^{-1}as PoE at 20- 25 DAT	6759.00	8692.00
T_5	Bensulfuron methyl 0.6%+ Pretilacholr 6% GR 60+600 g ha^{-1} as PE and Triafamone 20% + Ethoxysulfuron10% WG 45+22.5g ha^{-1}as PoE at 20-25DAT	6824.00	8827.33
T_6	Bensulfuron methyl 0.6%+ Pretilacholr 6% GR 60+600 g ha^{-1} as PE and hand Weeding at 20-25DAT	6482.33	8398.00
T_7	Weed free-Hand weeding at 20 and 40 DAT	7186.00	9296.67
T_8	Weedycheck(No weeding)	3198.67	4454.33
	SE(m)±	192.66	258.22
	CD(P=0.05)	584.37	783.21

Conclusion
Based on the results, the present study demonstrated that effective weed management significantly improved weed control efficiency, reduced crop-weed competition, and enhanced both grain and straw yield of transplanted rice. Weed infestation markedly reduced rice yield, whereas efficient management practices enhanced productivity. Manual weeding (T_7) provided the best control but was highly labor-intensive. Sequential herbicide applications, particularly Bensulfuron methyl + Pretilachlor (PE) followed by Florpyrauxifen-benzyl + Penoxsulam (T_1) and Bensulfuron methyl + Pretilachlor (PE) followed by Florpyrauxifen-benzyl + Cyhalofop-butyl (T_2), were equally effective, achieving high weed control efficiency (>89%) and higher grain yields. Therefore, these herbicidal options can be recommended as practical and sustainable alternatives to manual weeding in transplanted rice.

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