Impact of Early Post-Emergence Herbicides and Weeding Schedules on Weed Dynamics and Yield of Transplanted Rice

Abstract

Weeds pose a significant threat to rice productivity by competing for essential resources, especially during the early stages of crop establishment. A field experiment was conducted by ADT - 43 rice variety to evaluate the efficacy of selected early post-emergence (EPOE) herbicides, in combination with hand weeding, on weed control, dry matter production, weed control efficiency (WCE), yield and economic returns in transplanted rice during *Navarai* season 2024. The experiment was laid out in a Randomized Block Design (RBD) comprising eight treatments with three replications. Among the eight treatments, application of Triafamone @ 45 g a.i. ha^{-1} on 10 DAT followed by hand weeding at 40 DAT (T_4) recorded the lowest total weed population and dry matter production**,** with the highest WCE at both 30 and 60 DAT. This treatment also led to maximum grain yield, straw yield, net income, and benefit-cost ratio (BCR) (2.16), indicating superior weed suppression and economic viability**.** Pyrazosulfuron ethyl @ 21 g a.i. ha^{-1} + hand weeding at 40 DAT (T_8) was the next best alternative. Conversely, the unweeded control exhibited maximum weed growth and the lowest yield and economic returns. These results highlight the critical importance of integrating EPOE herbicide application with timely manual intervention to ensure effective weed control and economic sustainability in rice cultivation.

Keywords: Early post-emergence herbicide, Grain yield, Triafamone, WCE.

Introduction

Rice (*Oryza sativa* L.) is the principal food crop for more than half of the world's population, with India being a major producer and consumer. Transplanted rice ecosystems are highly vulnerable to weed competition during the initial crop establishment phase. In India, it is cultivated over 47.82 million hectares, with a production of 137.83 million metric tons and a productivity of 2.88 t ha^{-1}. In Tamil Nadu the rice was cultivated under an area of 2.16 million ha, with a production of 7.56 million tonnes and 3.5 tonnes ha^{-1} of productivity (Agricultural statistics at a glance, 2022-2023)[1]. Weeds compete vigorously with the rice crop for light, nutrients, and moisture, resulting in substantial yield reductions, sometimes exceeding 50% under uncontrolled conditions.

Traditionally, manual weeding at 20 and 40 days after transplanting (DAT) has been practiced for weed management. However, rising labour costs and seasonal unavailability of workers have made this practice economically and logistically unsustainable. This has prompted a shift towards chemical weed management strategies, particularly early post-emergence (EPOE) herbicides**,** which offer precise and timely control of weeds during their most vulnerable stages.

EPOE herbicides such as Triafamone, Pyrazosulfuron ethyl, and Ethoxysulfuron have shown promise in controlling a broad spectrum of weeds, including sedges, grasses, and broadleaf species. However, herbicide efficacy can vary depending on environmental conditions, weed flora, and application timing. Additionally, integrating herbicide application with manual weeding has been proposed as a viable strategy to manage late-emerging or herbicide-resistant weeds.

Despite the growing use of EPOE herbicides in rice ecosystems, limited data is available on their comparative efficacy, residual effects, and economic feasibility when used alone or in combination with manual weeding under transplanted conditions. Therefore, the present study was undertaken to evaluate the impact of selected EPOE herbicides and integrated weed management practices on weed dynamics, dry matter production, weed control efficiency (WCE), grain yield, net returns, and benefit-cost ratio (BCR) in transplanted rice.

Materials and Methods

A field investigation was conducted by the ADT-43 rice variety at Field A4, Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, during the *Navarai* season (January to May 2024). 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 treatment was arranged by single factor of eight in a Randomized Block Design (RBD) with three replications. The treatment details are as follows:

- T_1 – Unweeded control
- T_2 – Two hand weedings at 15 and 30 DAT
- T_3 – EPOE application of Triafamone @ 45 g a.i. ha^{-1} on 10 DAT + Hand weeding on 30 DAT
- T_4 – EPOE application of Triafamone @ 45 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT

- T_5 – EPOE application of Ethoxysulfuron @ 15 g a.i. ha^{-1} on 10 DAT + Hand weeding on 30 DAT
- T_6 – EPOE application of Ethoxysulfuron @ 15 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT
- T_7 – EPOE application of Pyrazosulfuron ethyl @ 21 g a.i. ha^{-1} on 10 DAT + Hand weeding on 30 DAT
- T_8 – EPOE application of Pyrazosulfuron ethyl @ 21 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT

The experimental field was prepared for transplanting by levelling and then ploughing with a tractor to create a fine tilth. The dimensions of each treatment plot were 5 × 4 m. The crop was grown in accordance with the region-specific agronomic guidelines.

The herbicides used were selective wettable granules (WG formulation). The products were uniformly applied by mixing the specified herbicide dose with sand and broadcasted @ 50 kg ha^{-1} over the plot surface at 10 DAT, as per the treatment protocol.

At the stages of 30 and 60 DAT, the quadrat of 0.25 m^2 area placed at random in each net plot and the weeds falling within the frames of the quadrat were counted and then oven dried at 80° C ± 5° C for 48 hours. Then the collected weeds are weighed and recorded. The data on weed counts were transformed using the formula ($\sqrt{x+0.5}$) and all the recorded data were analysed statistically with analysis of variance using Agres software with a critical difference at 0.05 level of probability.

Results and Discussion

Weed flora

The major weed flora of the experimental field during the cropping season *Navarai* were *Echinochloa colonum, Leptochloa chinensis* among grasses, *Cyperus rotundus* among sedge, and *Bergia capensis*, *Eclipta alba and Sphenoclea zeylanica* among broad leaved weeds.

Total Weed Population

The different early post-emergence (EPOE) herbicide treatments significantly influenced the total weed population (Table 1). The EPOE application of Triafamone @ 45 g a.i. ha^{-1} on 10 DAT followed by hand weeding on 40 DAT (T_4) recorded the lowest total weed population at all stages of crop growth. The herbicide combinations reduced the total weed density from 55.98 to 87.16 and 56.87 to 81.15 per cent at 30 and 60 DAT, respectively compared to unweeded control. The substantial reduction is attributed to Triafamone's mechanism of action is an ALS-inhibitor that impedes the biosynthesis of branched-chain amino acids, causing weed mortality or severe stunting. The follow-up hand weeding at 40 DAT effectively controlled later-emerging weeds, particularly those escaping initial herbicide action. This findings support with the result of Yadav *et al*., (2019)[2].

A similar trend was observed with Pyrazosulfuron ethyl @ 21 g a.i. ha^{-1} on 10 DAT followed by hand weeding at 40 DAT (T_8), which reduced total weed population by 80.74% at 30 DAT and 77.33% at 60 DAT. The Pyrazosulfuron is another ALS inhibitor which helps to arrest weed growth by stopping cell division, particularly in sedges and broadleaf weeds.

Ethoxysulfuron @ 15 g a.i. ha^{-1} on 10 DAT followed by hand weeding at 40 DAT (T_6) showed a moderate reduction in weed population (55.98% at 30 DAT and 56.87% at 60 DAT), while twice hand weeding (T_2) managed to suppress weeds by 49.26% and 51.69% at the respective intervals. Though physical removal was effective, it lacked the residual effect provided by herbicides.

In contrast, unweeded control (T_1) recorded the highest total weed population, due to the absence of any control measures, which allowed weeds to flourish unchecked. These results corroborate findings of Saikia *et al.* (2025)[3], who reported similar trends under unweeded conditions.

Overall, herbicide application followed by hand weeding on 40 DAT was more effective than hand weeding on 30 DAT, likely due to the coverage of late-emerging weeds and better canopy-induced suppression after weeding.

Weed dry matter production

Weed dry matter production (DMP) was also significantly affected by treatments. The lowest weed biomass was observed in EPOE application of Triafamone @ 45 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT (T_4) with an 86.22% reduction at 30 DAT and 81.38% at 60 DAT over the unweeded control (Table 1). The reduced DMP aligns with the lower weed population, showing effective suppression due to Triafamone's early action and follow-up manual control.

EPOE application of Pyrazosulfuron ethyl @ 21 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT (T_8) followed with DMP reductions of 81.63% (30 DAT) and 76.35% (60 DAT). Again, this performance can be attributed to the effective mode of action and complementary manual control which reduce the total weed population.

Twice hand weeding (T2) also lowered weed DMP by 49.26% and 51.69%, respectively.

Unweeded plots (T1) exhibited the highest DMP, likely due to uninterrupted weed growth and nutrient competition, leading to dense weed biomass accumulation. This result supports the findings of Ramesh *et al.* (2022)[4] and reinforces the importance of integrated weed management.

Weed Control Efficiency (WCE)

WCE values varied significantly across treatments. At 30 DAT, the values ranged from 55.98 to 87.16 per cent, and at 60 DAT, from 56.87 to 81.15 per cent. The highest WCE was recorded in EPOE application of Triafamone @ 45 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT (T_4), reflecting the most effective weed suppression across stages. This was followed by EPOE application of Pyrazosulfuron ethyl @ 21 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT (T_8) (Table 1).

Twice hand weeding (T2) yielded lower WCEs (49.26% and 51.69% at 30 and 60 DAT), possibly due to rapid weed re-emergence between manual operations. The lowest WCE was found in the unweeded control (T1) due to unchecked weed proliferation. These outcomes agree with Saravanane (2020)[5].

Grain and Straw Yield (kg ha^{-1})

Yield was significantly affected by weed management strategies. EPOE application of Triafamone @ 45 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT (T_4) produced the highest grain yield (5.76 t ha^{-1}) and straw yield (8.96 t ha^{-1}) followed by (T_8) produced the grain yield (5.41 t ha^{-1}) and straw yield (8.62 t ha^{-1}) (Table 2). These treatments also had the highest straw yields (8.96 and 8.20 t ha^{-1}, respectively). The improved yield is attributed to higher LAI, productive tillers, and filled grains, all enhanced by timely weed suppression.

On the other hand, Unweeded control (T_1) produced the lowest grain yield (2.81 t ha^{-1}) and straw yield (5.06 t ha^{-1}), confirming the detrimental effect of unmanaged weed competition on resource use efficiency and biomass partitioning. This result was followed by Mir *et al*., (2024)[6]; Rao *et al*., (2022)[7].

The comprehensive evaluation of growth and yield parameters confirms that early application of herbicides alone is not sufficient. Rather, combining EPOE herbicides with a strategic hand weeding, particularly at 40 DAT, offers the most effective control of both early and late-emerging weed flushes. Among all, Triafamone @ 45 g a.i. ha^{-1} on 10 DAT + Hand Weeding on 40 DAT (T_4) consistently outperformed all treatments across growth, yield attributes, and final yield metrics.

These findings are in close agreement with prior studies by Arthanari (2023)[8] and Manisankar *et al*. (2021)[9], emphasizing that synchronized chemical and manual weed control strategies during the crop's critical growth phases are key to maximizing yield in transplanted rice.

Net Income

Economic analysis revealed that the EPOE application of Triafamone @ 45 g a.i. ha^{-1} on 10 DAT + Hand weeding on 30 DAT (T_4) recorded with the net income of Rs.76009.70. This was followed by the EPOE application of Pyrazosulfuron ethyl @ 21 g a.i. ha^{-1} on 10 DAT + Hand weeding on 40 DAT (T_8) which recorded with the net income of Rs. 72189.70 (Table 2). The better control of weeds on application of herbicides *fb* hand weeding favoured the crop growth and yield. The increased yield and reduced cost of cultivation might be the reasons for increased net income in these treatments. Even though the labour charge for handweeding and the cost of herbicide were high, the higher grain yield gives the highest net income. The Unweeded control (T_1) was found with the lowest net income, even though there is a lowest cost of cultivation, due to the higher weed infestation and higher yield reduction leads to the lowest net income. These observations support the findings of Nazir *et al.* (2020)[10].

Benefit Cost Ratio (BCR)

The early post emergence application of Triafamone @ 45 g ai ha^{-1} on 10 DAT + handweeding on 40 DAT (T_4) recorded with the highest benefit cost ratio over the other treatments BCR. The next highest was recorded in the early post emergence application of Pyrazosulfuron ethyl @ 21 g ai ha^{-1} on 10 DAT + handweeding on 40 DAT (T_8) (Table 2). Two times hand weeding increase Rs. 17,600 and it is Rs. 5160, 7180 and 7860 higher compared to Triafamone, Pyrazosulfuron, Ethoxysulfuron *fb* hand weeding respectively. This might be one of the reasons for low BCR observed in twice hand weeding. Due to the scarcity of labour particularly during the critical period and higher labour wages make hand weeding less economic and feasible. Application of herbicides *fb* hand weeding resulted lesser cost of cultivation compared to twice hand weeding. The EPOE herbicides control the weeds earlier and late emerging weeds are controlled by single hand weeding on 40 DAT was managing complex weed flora during a critical period of crop weed competition. The effective and timely application of early post emergence herbicides and handweeding resulted the less weed infestation and higher yield which reduced the cost of cultivation and increased the Benefit cost ratio.

The least benefit cost ratio was observed in the Unweeded control (T_1). This might be due to the competition between the crop and weed caused by the unrestricted weed infestation throughout the experiment, which affects the crop growth and yield components and reduced the crop yield. These findings are consistent with Bindu *et al*. (2023)[11].

Conclusion

The study clearly demonstrates that early post-emergence (EPOE) herbicides, when integrated with timely manual weeding, significantly improved weed suppression, crop productivity, and economic returns in transplanted rice. Among the treatments evaluated, Triafamone @ 45 g a.i. ha^{-1} applied at 10 DAT followed by hand weeding at 40 DAT was the most effective in minimizing total weed population and dry matter production, while achieving the highest weed control efficiency (WCE), grain yield, net income, and benefit-cost ratio

(BCR). This integrated approach ensured efficient control of both early and late-emerging weed species and improved overall resource use efficiency.

Table 1. Response of early post emergence herbicides application on total weed population (m^{-2}), weed dry matter production ($g\ m^{-2}$), weed control efficiency on 30 and 60 DAS in in transplanted rice

Treatments	Total weed population (m^{-2})		Weed dry matter production ($g\ m^{-2}$)		WCE %	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
T_1 – Unweeded control	10.47 (109.03)	14.59 (212.24)	9.71 (93.86)	15.98 (254.82)	-	-
T_2 – Twice hand weeding @ 15 and 30 DAT	7.47 (55.32)	10.15 (102.54)	6.97 (48.02)	11.83 (139.53)	49.26	51.69
T_3 – EPOE application of Triafamone @ 45 g ai ha^{-1} on 10 DAT + Hand weeding on 30 DAT	5.24 (27)	7.65 (58)	4.77 (22.29)	8.67 (74.73)	75.24	72.67
T_4 – EPOE application of Triafamone @ 45 g ai ha^{-1} on 10 DAT + Hand weeding on 40 DAT	3.81 (14)	6.36 (40)	3.66 (12.93)	6.93 (47.46)	87.16	81.15
T_5 – EPOE application of Ethoxysulfuron @ 15 g ai ha^{-1} on 10 DAT + Hand weeding on 30 DAT	6.96 (48)	9.59 (91.54)	6.84 (46.30)	11.28 (126.75)	55.98	56.87
T_6 – EPOE application of Ethoxysulfuron @ 15 g ai ha^{-1} on 10 DAT + Hand weeding on 40 DAT	6.36 (40)	8.97 (80)	5.94 (34.79)	10.42 (108.13)	63.31	62.31
T_7 – EPOE application of Pyrazosulfuron ethyl @ 21 g ai ha^{-1} on 10 DAT + Hand weeding on 30 DAT	5.79 (33)	8.34 (69)	5.36 (28.26)	9.52 (90.12)	69.73	67.49
T_8 – EPOE application of Pyrazosulfuron ethyl @ 21 g ai ha^{-1} on 10 DAT + Hand weeding on 40 DAT	4.64 (21)	6.97 (48.12)	4.23 (17.24)	7.79 (60.26)	80.74	77.33
S.Ed	0.24	0.27	0.24	0.38		
CD (p=0.05)	0.52	0.59	0.52	0.82		

Table 2. Response of early post emergence herbicides application on yield (kg ha^{-1}) and economics in rice

Treatments	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})	Net Income (Rs)	BCR
T_1 – Unweeded control	2.60	5.65	12259.70	1.23
T_2 – Twice hand weeding @ 15 and 30 DAT	4.41	7.26	37899.70	1.54
T_3 – EPOE application of Triafamone @ 45 g ai ha^{-1} on 10 DAT + Hand weeding on 30 DAT	5.26	8.32	65689.70	2.03
T_4 – EPOE application of Triafamone @ 45 g ai ha^{-1} on 10 DAT + Hand weeding on 40 DAT	5.76	8.96	76009.70	2.16
T_5 – EPOE application of Ethoxysulfuron @ 15 g ai ha^{-1} on 10 DAT + Hand weeding on 30 DAT	4.45	7.38	46119.70	1.73
T_6 – EPOE application of Ethoxysulfuron @ 15 g ai ha^{-1} on 10 DAT + Hand weeding on 40 DAT	4.70	7.69	52179.70	1.82
T_7 – EPOE application of Pyrazosulfuron ethyl @ 21 g ai ha^{-1} on 10 DAT + Hand weeding on 30 DAT	4.90	8.01	57779.70	1.92
T_8 – EPOE application of Pyrazosulfuron ethyl @ 21 g ai ha^{-1} on 10 DAT + Hand weeding on 40 DAT	5.50	8.62	72189.70	2.15
S.Ed	0.106	0.15		
CD (p=0.05)	0.187	0.27		

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