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Prospects of ready-mix herbicides for weed management in transplanted rice (*Oryza sativa* L.) in the southern laterites of Kerala, India

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Abstract
A study was conducted at the Instructional Farm attached to the College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Kerala, during the period from 01 November 2024 to 13 February 2025 to assess the efficacy of novel ready-mix herbicides in managing the weeds in transplanted rice. The experiment was conducted using a randomized complete block design with eight treatments which included three ready-mix herbicides, *viz*., penoxsulam + cyhalofop-butyl (T_1), florpyrauxifen-benzyl + cyhalofop-butyl (T_2) and florpyrauxifen-benzyl + penoxsulam (T_3), three straight herbicides, *viz*., penoxsulam (T_4), cyhalofop-butyl (T_5) and florpyrauxifen-benzyl (T_6), compared against hand weeding at 15 days after transplanting (DAT) and 30 DAT (T_7) and unweeded control (T_8). All the herbicides were applied at 15 DAT. A mixed composition of weeds comprising grasses (*Isachne miliacea* and *Echinochloa colona*), sedge (*Cyperus exaltatus*), broad-leaf weed (*Limnocharis flava*), and fern *Salvinia molesta* was observed in the experimental area. The results revealed lower weed density and weed dry weight in T_2 which was statistically comparable to hand weeding. Similarly, weed persistence index and nutrient removal by weeds were also lower in T_2. Herbicide efficiency index was observed to be superior in T_2. Higher weed control efficiency and crop resistance index were observed in hand weeding (T_7) which was at par with T_2. Weed index was noted to be the highest in unweeded control indicating the possibility of 70.59 per cent yield loss in transplanted rice due to the presence of weeds. Higher grain yield in hand weeding and lowest weed index (1.63%) was obtained in T_2. All the three ready-mix herbicides resulted in higher net return and B:C ratio compared to other treatments. The highest net income (₹ 48763 ha^{-1}) and B:C ratio (1.44) were realized with the early post-emergence application of florpyrauxifen-benzyl + cyhalofop-butyl (T_2). It could be concluded that weeds in transplanted rice could be managed efficiently and economically by the application of the early post-emergence ready-mix herbicide, florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1}) at 15 DAT.

Keywords: Ready-mix herbicides, florpyrauxifen-benzyl + cyhalofop-butyl, weed management, transplanted rice

1. Introduction

Rice (*Oryza sativa* L.) is the world's most significant staple food, feeding over half of mankind and accounting for almost 43 per cent of India's total food grain production (IPAD, 2024) [10]. It is grown in a variety of environments, from irrigated condition to rainfed lowlands, providing a living for millions of farmers and contributing significantly to global food security. Rice is cultivated on around 50 million hectares in India, producing 217.52 million tonnes, with 1.97 lakh hectares in Kerala alone yielding 5.59 lakh tonnes (FIB, 2024) [4]. Despite their importance, weeds have a greater impact on rice yields than pests and diseases combined, resulting in yield reductions of 40-60 per cent and, in extreme circumstances, up to 96 per cent (Chauhan and Johnson, 2011) [2]. Weeds outcompete rice for nutrients, water, and light, resulting in more losses than pests and diseases combined. Manual weeding is becoming increasingly impractical due to high labour expenses, making herbicides the best solution. However, reliance on a single herbicide has led to weed resistance and weed shift. Ready-mix post-emergence herbicide combinations offer broader-spectrum control, lower resistance risk, and increase yield and profitability (Mondal *et al*., 2019; Geetha *et al*., 2022) [15, 6]. In this background, the present study aimed to assess the efficacy and economics of specific ready-mix herbicides in transplanted rice.

2. Materials and Methods

The experiment was conducted in the wetlands at the Instructional Farm, Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India, during the period from 01 November 2024 to 13 February 2025. The experimental site was located at 8º 25’ 49” N latitude and 76º 59’ 02” E longitude and at an altitude of 24 m above mean sea level. The soil of the experimental site was sandy clay loam in texture, strongly acidic (pH of 5.37) in reaction, with a high organic carbon (1.99%) content. The soil could be rated as having a medium level of available nitrogen (520 kg ha^{-1}) and available potassium (183.1 kg ha^{-1}), and high available phosphorus (28.2 kg ha^{-1}). The experimental site is characterized by a warm, humid tropical climate. The weather data on mean temperature, and rainfall were averaged over the meteorological standard weeks. The range of the mean maximum temperature and mean minimum temperature were between 31.5 ºC to 32.9 ºC, and 19.9 ºC to 23.6 ºC, respectively and a total rainfall of 152.8 mm was recorded during the cropping period. The rice variety chosen for the study was KAU Manuratna, a semi-dwarf, high yielding variety with short duration (95-99 days). Eighteen-day old seedlings raised in a nursery were transplanted at a spacing of 15 cm x 10 cm. Well decomposed dry cow dung containing 0.52 per cent N, 0.21 per cent P_2O_5 and 0.45 per cent K_2O was used as the organic manure source. A nutrient recommendation of 70:35:35 kg ha^{-1} N, P and K were applied as urea (46% N), rajphos (20% P_2O_5) and muriate of potash (60% K_2O) as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 2024).

The field experiment was conducted using a randomized complete block design (RCBD) with eight treatments replicated thrice. The treatments included three ready-mix herbicides [T_1: (penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1}, T_2: florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1}), and T_3: florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})], three straight herbicides [T_4: (penoxsulam 2.67% OD (25 g ha^{-1}), T_5: cyhalofop-butyl 10.1% EC (80 g ha^{-1}) and T_6: florpyrauxifen-benzyl 2.7% EC (31.25 g ha^{-1})], T_7: hand weeding at 15 days after transplanting (DAT) and 30 DAT and T_8: unweeded control. The herbicides were applied at 15 DAT.

The data on weeds were recorded at 60 DAT and at harvest. Absolute weed density was recorded placing 25 cm x 25 cm quadrate at random in four sites in each plot and mean value was calculated. The weeds were categorised into grasses, broad-leaf weeds, sedges and ferns. Weed samples were collected from the area left aside for taking destructive samples. Weeds which got included inside the quadrate were pulled out carefully with roots intact, washed, dried under shade and then oven dried at (65 ± 5) °C to a constant weight. After oven drying, the weed dry weight was recorded. The absolute weed density and weed dry weight were computed to per meter square values. The absolute weed density values were subjected to square root transformation i.e. $\sqrt{x + 0.5}$ for statistical analysis. Different weed indices *viz*. weed index (WI) (Gill and Vijaykumar, 1969) [8], weed control efficiency (WCI) (Mani and Gautham, 1973) [13], herbicide efficiency index (HEI) (Krishnamurthy *et al*., 1975) [11], weed persistence index (WPI) (Mishra and Misra, 1997) [14], crop resistance index (CRI) (Sarma, 2016) [23] were calculated using following equations.

$$\text{WI} = \frac{\text{Yield from weed free plot} - \text{Yield from treated plot}}{\text{Yield from weed free plot}} \text{ x } 100$$

$$\text{WCE} = \frac{\text{Weed dry weight in unweed plot} - \text{Weed dry weight in treated plot}}{\text{Weed dry weight in unweeded (control) plot}} \text{ x } 100$$

$$\text{HEI} = \frac{\frac{\text{Yield from treated plot} - \text{Yield from control plot}}{\text{Yield from treated plot}} \text{ X } 100}{\frac{\text{Weed dry matter in treated plot}}{\text{Weed dry matter in control plot}} \text{ X } 100}$$

$$\text{WPI} = \frac{\text{Weed dry matter in treated plot}}{\text{Weed dry matter in control plot}} \text{ x } \frac{\text{Weed count in control plot}}{\text{Weed count in treated plot}}$$

$$\text{CRI} = \frac{\text{Dry matter production of crop in treated plot}}{\text{Dry matter production of crop in control plot}} \text{ x } \frac{\text{Weed dry matter in control plot}}{\text{Weed dry matter in treated plot}}$$

The nutrient (NPK) removal by weeds were calculated at 60 DAT and at harvest. Weeds samples were collected, oven dried, ground, sieved through a 0.5 mm sieve and subjected to acid extraction and analysed for their N, P, K contents. Grain yield from different plots were recorded at harvest. Economics of cultivation was worked out based on the price of market produce. The entire statistical analysis was done using the R and AI solutions for inferential statistics (RAISINS), the online statistical analysis platform of Kerala Agricultural University.

3. Results and Discussion

Effect on weeds

Weed flora

The experimental field was infested with complex weed flora comprising grasses, sedge, broad-leaf weed and fern. The grasses which were predominant in the field were *Isachne miliacea* and *Echinochloa colona*. The sole sedge observed in the field was *Cyperus exaltatus*. The broad-leaf weed included *Limnocharis flava*, and a fern *Salvinia molesta*.

Absolute density of weeds

The results revealed that the absolute density of weeds were significantly influenced by the treatments (Table 1). The absolute density of weeds at 60 DAT was lower (9.67 no. m^{-2}) in T_7 (hand weeding at 15 DAT and 30 DAT) which was observed to be statistically comparable with treatments T_2 (12.00 no. m^{-2}), T_1 (12.33 no. m^{-2}), and T_3 (12.67 no. m^{-2}). On the contrary, the treatments T_4 (18.67 no. m^{-2}), T_5 (19.00 no. m^{-2}), and T_6 (21.67 no. m^{-2}) remained at par with comparatively higher absolute density of weeds. Unweeded control (T_8) exhibited the highest absolute density of weeds (57.00 no. m^{-2}). An almost a similar trend was noted during the harvest stage also. The treatments T_2 and T_7 resulted in statistically comparable and moreover lower absolute weed density (16.67 no. m^{-2} and 15.00 no. m^{-2} respectively). Further, the treatment T_1 (21.33 no. m^{-2}) remained at par with T_2, and T_3 (22.00 no. m^{-2}). While the treatments, T_4 (32.00 no. m^{-2}) and T_5 (33.67 no. m^{-2}) were statistically at par, the treatments T_5 and T_6 (39.00 no. m^{-2}) remained comparable with higher absolute density of weeds. This reduction in weed density could be attributed to the early knockdown and broad-spectrum effect of cyhalofop-butyl which targets grassy weeds by inhibiting acetyl-CoA carboxylase (ACCase), whilst florpyrauxifen-benzyl mimics the growth regulator auxin to disrupt broad-leaf metabolism, resulting in dual suppression. This herbicide mixture disrupts photosynthesis and cell elongation simultaneously, preventing regrowth and new emergence of the weeds. These findings are aligned with Rizal and Arbiwati (2024) [21], Venkatesh *et al*. (2021) [28], who revealed that the same herbicide mixture florpyrauxifen-benzyl + cyhalofop-butyl achieved near complete suppression of weeds in direct seeded rice and it resembles the control spectrum of manual weeding, showing their value in labour-scarce areas.

Weed dry weight

Weed dry weight recorded at 60 DAT and at harvest stages of transplanted rice varied significantly in response to the different treatments (Table 1). At 60 DAT, weed dry weight was observed to be lower (2.42 ± 0.38 g m^{-2}) with hand weeding at 15 DAT and 30 DAT (T_7), and it was statistically on a par with T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] (2.67 ± 0.14 g m^{-2}) and T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})] (3.42 ± 0.29 g m^{-2}). Further, the treatments T_1 and T_2 were comparable with T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] (3.50 ± 0.43 g m^{-2}). Weed dry weight was noted to be comparatively higher and statistically comparable in T_4 (4.67 ± 0.80 g m^{-2}), T_5 (4.75 ± 0.25 g m^{-2}), and T_6 (5.43 ± 1.21 g m^{-2}). At harvest stage the treatments T_7 and T_2 were equally effective in reducing the weed dry weight, as evinced by lower values (3.92 ± 1.04 g m^{-2}, and 4.17 ± 1.04 g m^{-2} respectively). The treatments T_2 was statistically on a par with T_1 (5.33 ± 1.51 g m^{-2}) and T_3 (5.50 ± 0.25 g m^{-2}). While the treatment T_4 (8.00 ± 1.50 g m^{-2}) remained comparable with T_5 (8.42 ± 0.52 g m^{-2}), the treatment T_5 was at par with T_6 (9.75 ± 0.66 g m^{-2}). Weedy check (T_8) had the highest weed dry weight at 60 DAT (14.25 g m^{-2}) and at harvest (23.58 g m^{-2}) stages of transplanted rice. The reduction in biomass under T_2 could be due to its dual effect, which kill weeds quickly while restricting dry matter build-up. Suppressing biomass is particularly critical in transplanted rice, where dense weed canopies shade the crops inducing tiller mortality. By preventing biomass accumulation, T_2 not only reduced the competitions for resources but also minimized the potential seed rain, helping break the weed cycle. These findings are aligned with Ahmed *et al.* (2021) [1]. Gustavo *et al.* (2018) [9] also reported florpyrauxifen-benzyl effectively controlled sedges and broadleaved weeds reducing weed biomass.

Weed control efficiency

Weed control efficiency was observed to vary significantly among the treatments (Table 1). At 60 DAT, the treatment T_7 (hand weeding at 15 DAT and 30 DAT) resulted in higher weed control efficiency of 82.60% ± 4.98%. However, it was statistically comparable with T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] (81.04% ± 3.02%), T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})] (75.77% ± 3.41%), and T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] (75.40% ± 1.21%). The treatments T_4, T_5 and T_6 comprising straight herbicides were statistically at par and resulted in comparatively lower weed control efficiency at 60 DAT (66.41% ± 9.74%, 66.21% ± 5.36%, and 62.25% ± 5.23% respectively). At harvest stage, it was observed that the treatment comprising hand weeding at 15 DAT and 30 DAT (T_7) and the treatment wherein the ready-mix herbicide florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC at 150 g ha^{-1} (T_2) was applied were equally effective in terms of weed control efficiency (83.28% ± 4.90% and 82.22% ± 4.94% respectively). Furthermore, the weed control efficiency achieved with the treatment T_2 remained statistically comparable with T_1 (77.23% ± 7.06%) and T_3 (76.68% ± 0.43%). It was followed by T_4 (penoxsulam 2.67% OD at 25 g ha^{-1}) (65.92% ± 7.39%) and T_5 (cyhalofop-butyl 10.1% EC at 80 g ha^{-1}) (64.28% ± 2.65%) which were again comparable in terms of weed control efficiency. The treatment T_6 (florpyrauxifen-benzyl 2.7% EC at 31.25 g ha^{-1}) had lower weed control efficiency (58.59% ± 3.70%) and it remained on a par with T_5. WCE was noted to be the highest in T_2 and T_7, both of which had lower absolute density of weeds and weed dry weight at the critical growth stages of rice. As WCE is inversely proportional to weed dry weight, T_2 recorded values very close to hand weeding due to its strong early post-emergence action and dual suppression on weeds. Similar findings have been reported by Mondal *et al.* (2020) [16], Sreedevi *et al.* (2020) [25], and Padmaja and Ramprakash (2022) [18] also reported superior WCE with florpyrauxifen-benzyl herbicide mixtures compared to single applications. The results are in conformity with those of Sreedevi *et al.* (2020) [25] and Mahapatra *et al.* (2023) [12].

Table 1: Effect of straight and ready-mix herbicides on absolute weed density, weed dry weight and weed control efficiency in transplanted rice

Treatment		Absolute density of weeds (no. m^{-2})		Weed dry weight (g m^{-2})		Weed control efficiency (%)	
		60 DAT	Harvest	60 DAT	Harvest	60 DAT	Harvest
T_1	Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})	3.50^{b} (12.33)	4.59^{cd} (21.33)	3.42 ± 0.29^{bc}	5.33 ± 1.51^{c}	75.77 ± 3.41^{a}	77.23 ± 7.06^{b}
T_2	Florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})	3.46^{b} (12.00)	4.06^{de} (16.67)	2.67 ± 0.14^{bc}	4.17 ± 1.04^{cd}	81.04 ± 3.02^{a}	82.22 ± 4.94^{ab}
T_3	Florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63+25) g ha^{-1})	3.55^{b} (12.67)	4.69^{c} (22.00)	3.50 ± 0.43^{b}	5.50 ± 0.25^{c}	75.40 ± 1.21^{a}	76.68 ± 0.43^{b}
T_4	Penoxsulam 2.67% OD (25 g ha^{-1})	4.31^{a} (18.67)	5.64^{b} (32.00)	4.67 ± 0.80^{a}	8.00 ± 1.50^{b}	66.41 ± 9.74^{b}	65.92 ± 7.39^{c}
T_5	Cyhalofop-butyl 10.1% EC (80 g ha^{-1})	4.36^{a} (19.00)	5.80^{ab} (33.67)	4.75 ± 0.25^{a}	8.42 ± 0.52^{ab}	66.21 ± 5.36^{b}	64.28 ± 2.65^{cd}
T_6	Florpyrauxifen-benzyl 2.7% EC (31.25 g ha^{-1})	4.63^{a} (21.67)	6.24^{a} (39.00)	5.43 ± 1.21^{a}	9.75 ± 0.66^{a}	62.25 ± 5.23^{b}	58.59 ± 3.70^{d}
T_7	Hand weeding at 15 DAT and 30 DAT	3.10^{b} (9.67)	3.84^{e} (15.00)	2.42 ± 0.38^{c}	3.92 ± 1.04^{d}	82.60 ± 4.98^{a}	83.28 ± 4.90^{a}
T_8	Unweeded control (weedy check)	57.00	94.33	14.25	23.58	-	-
SE m (±)		0.20	0.20	0.46	0.35	1.89	2.47
CD (p = 0.05)		0.600	0.630	1.400	1.080	5.820	7.620

Absolute density of weeds: original values in parentheses and the data were subjected to square root transformation

Table 2: Effect of straight and ready-mix herbicides on herbicide efficiency index, weed persistence index and crop resistance index in transplanted rice.

Treatment		Herbicide efficiency index (%)		Weed persistence index (%)		Crop resistance index (%)	
		60 DAT	Harvest	60 DAT	Harvest	60 DAT	Harvest
T_1	Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})	2.76 ± 0.29^{b}	3.10 ± 0.92^{bc}	0.24 ± 0.03^{b}	0.23 ± 0.07^{c}	9.26 ± 0.58^{b}	10.30 ± 2.44^{b}
T_2	Florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})	3.75 ± 0.48^{a}	4.16 ± 1.15^{ab}	0.19 ± 0.03^{b}	0.18 ± 0.05^{cd}	13.36 ± 1.75^{a}	14.66 ± 3.03^{a}
T_3	Florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63+25) g ha^{-1})	2.65 ± 0.08^{bc}	2.84 ± 0.16^{cd}	0.25 ± 0.01^{b}	0.23 ± 0.02^{c}	8.89 ± 0.44^{bc}	9.40 ± 0.89^{b}
T_4	Penoxsulam 2.67% OD (25 g ha^{-1})	1.96 ± 0.54^{cd}	1.92 ± 0.38^{de}	0.34 ± 0.10^{a}	0.34 ± 0.07^{b}	6.37 ± 1.48^{cd}	6.15 ± 1.05^{c}
T_5	Cyhalofop-butyl 10.1% EC (80 g ha^{-1})	1.87 ± 0.25^{cd}	1.75 ± 0.09^{e}	0.34 ± 0.05^{a}	0.36 ± 0.03^{ab}	6.08 ± 0.67^{d}	5.69 ± 0.25^{c}
T_6	Florpyrauxifen-benzyl 2.7% EC (31.25 g ha^{-1})	1.66 ± 0.27^{d}	1.50 ± 0.08^{e}	0.38 ± 0.05^{a}	0.41 ± 0.04^{a}	5.46 ± 1.06^{d}	4.91 ± 0.09^{c}
T_7	Hand weeding at 15 DAT and 30 DAT	-	-	0.17 ± 0.05^{b}	0.17 ± 0.05^{d}	15.45 ± 3.01^{a}	16.21 ± 3.75^{a}
T_8	Unweeded control (weedy check)	-	-	-	-	-	-
SE m (±)		0.25	0.35	0.02	0.02	0.84	1.02
CD (p = 0.05)		0.780	1.080	0.080	0.060	2.60	3.160

Herbicide efficiency index

The herbicide efficiency index varied significantly among the different herbicide tested from treatments T_1 to T_6 (Table 2). Among the herbicides tested, at 60 DAT, the treatment T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] resulted in higher for herbicide efficiency index (3.75% ± 0.48%). It was followed by T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})] (2.76% ± 0.29%) and T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] (2.65% ± 0.08%) which remained statistically comparable. Furthermore, while the treatments T_3, T_4, and T_5 were statistically similar with lower herbicide efficiency indices, the treatments T_4, T_5, and T_6 were observed to be at par. The herbicide efficiency index computed during the harvest stage also followed a similar trend with the treatment T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] proving efficient with 4.16% ± 1.15% efficiency. It was statistically comparable with hand weeding at 15 DAT and 30 DAT (T_7) which had a HEI of 4.48% ± 1.34%. Further, the treatments T_2 and T_1 (3.10% ± 0.92%) were at par. The HEI of straight herbicides in T_4 (1.92% ± 0.38%), T_5 (1.75% ± 0.09%) and T_6 (1.50% ± 0.08%) were lower and statistically on a par. The higher HEI in T_2 could be attributed due to its dual action, which broadens the spectrum and reduces weed regrowth, early application timing that coincides with the most vulnerable stage of weeds and substantial yield improvement. Similar findings were reported by Chaudhary *et al.* (2021). Ghosh *et al.* (2025) [7] also observed that florpyrauxifen-benzyl based herbicide mixtures produced higher WCE and profitability resulting in higher HEI in transplanted rice.

Weed persistence index

Weed persistence index was noted to be significantly influenced by the weed management practices tested (Table 2). At 60 DAT, the treatments T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})], T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] and T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] were observed to result in lower WPI (0.24% ± 0.03%, 0.19% ± 0.03%, and 0.25% ± 0.01% respectively) which was statistically as good as T_7 (hand weeding at 15 DAT and 30 DAT) (0.17% ± 0.05%). The WPI values were observed to be higher in T_4 (0.34% ± 0.10%), T_5 (0.34% ± 0.05%), and T_6 (0.38% ± 0.05%). At harvest stage, the treatment T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] and T_7 (hand weeding at 15 DAT and 30 DAT) were statistically comparable with lower WPI of 0.18% ± 0.05% and 0.17% ± 0.05% respectively. Further, the treatments comprising ready-mix herbicides, *viz.*, T_1 (0.23% ± 0.07%), T_2 (0.18% ± 0.05%) and T_3 (0.23% ± 0.02%) were equally effective in reducing the weed persistence. While the treatments, T_4 and T_5 resulted in comparatively higher and comparable WPI (0.34% ± 0.07%, and 0.36% ± 0.03% respectively), the treatments, T_5 and T_6 (0.41% ± 0.04%) were statistically comparable. Hand weeding at 15 DAT and 30 DAT physically removed almost all weeds resulting in lowest WPI, T_2 closely matched it by preventing germination and killing young weeds before establishment. Compared with penoxsulam + cyhalofop-butyl (T_1), T_2 performed better because florpyrauxifen-benzyl has stronger activity on broad-leave weeds and sedges, complementing cyhalofop-butyl's grass control also leaving fewer survivors by suppressing late emerging weed flushes.

Crop resistance index

At 60 DAT, the crop resistance index was observed to be significantly higher (15.45% ± 3.01%) in T_7 (hand weeding at 15 DAT and 30 DAT) and T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] (13.36% ± 1.75%), which were statistically at par (Table 2). It was followed by T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})] (9.26% ± 0.58%) and T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] (8.89% ± 0.44%) which were also statistically comparable. Further, the treatments T_3 and T_4 (6.37% ± 1.48%) were comparable and likewise the treatments, T_4, T_5 (6.08% ± 0.67%) and T_6 (5.46% ± 1.06%) were also statistically on a par with lower CRI. A similar trend was observed during the harvest stage also, with the treatment T_2 resulting in a CRI (14.66% ± 3.03%) which remained statistically comparable with T_7 (16.21% ± 3.75%). As at 60 DAT, it was followed by T_1 (10.30% ± 2.44%) and T_3 (9.40% ± 0.89%) which were at par. The treatments, T_4, T_5, and T_6 showed lower and comparable values for CRI (6.15% ± 1.05%, 5.69% ± 0.25%, and 4.91% ± 0.09%, respectively). Higher CRI values in T_2 and T_7 treatments suggest that effective weed management enhances rice vigour, allowing better canopy establishment and resource capture. The weed-free rice stands under florpyrauxifen-benzyl + cyhalofop-butyl herbicide mixture produced more tillers and greater canopy cover, leading to resilience against late weed emergence. Mahapatra *et al.* (2023) [12] also obtained similar findings.

Nitrogen removal by weeds

Nitrogen removal by weeds showed significant variation in response to the treatments imposed, both at 60 DAT and at harvest (Table 3). At 60 DAT, the treatments T_7 (1.55 ± 0.24 kg ha^{-1}), T_2 (1.92 ± 0.28 kg ha^{-1}), T_1 (1.97 ± 0.37 kg ha^{-1}), and T_3 (2.03 ± 0.22 kg ha^{-1}) exhibited lower nitrogen removal by weeds and these treatments were observed to be statistically at par. The nitrogen removal by weeds in treatments T_4, (2.99 ± 0.51 kg ha^{-1}) T_5, (3.04 ± 0.16 kg ha^{-1}) and T_6 (3.45 ± 0.82 kg ha^{-1}) were comparatively higher and remained statistically comparable. At harvest, nitrogen removal by weeds was observed to be lower and statistically comparable in the treatments T_7, T_2 and T_1 (2.67 ± 0.67 kg ha^{-1}, 3.12 ± 0.38 kg ha^{-1}, and 3.14 ± 0.96 kg ha^{-1} respectively). Additionally, the treatments T_1 and T_3 (4.43 ± 0.79 kg ha^{-1}), and the treatments T_3, T_4 (5.12 ± 0.96 kg ha^{-1}), and T_5 (5.39 ± 0.33 kg ha^{-1}) were statistically at par. Among the herbicides tested, nitrogen removal by weeds at 60 DAT was comparatively higher in T_6 (6.24 ± 0.42 kg ha^{-1}), but comparable with T_5. Nitrogen removal by weeds was observed to be the highest in the weedy check (T_8), both at 60 DAT (9.12 kg ha^{-1}) and at harvest (15.09 kg ha^{-1}) stages in transplanted rice. Nitrogen removal by weeds was markedly higher in T_8, reflecting the dense weed biomass and aggressive uptake of available soil N. In contrast, T_7 obtained lower N removal closely followed by T_2. This result highlights the critical role of early weed management in reducing nutrient removal from the soil. Nitrogen is vulnerable to removal by weeds due to its mobility in the soil and its role as a key driver of vegetative growth. By suppressing the weed emergence and growth at the critical early stages T_7 and T_2 minimised the establishment of large weed root systems, thereby reducing the N uptake by the weeds. These findings are aligned with Yadav *et al.* (2021) [29].

Table 3: Effect of straight and ready-mix herbicides on nitrogen, phosphorus and potassium removal by weeds in transplanted rice.

Treatment		Nutrient removal by weeds (kg ha^{-1})					
		Nitrogen		Phosphorus		Potassium	
		60 DAT	Harvest	60 DAT	Harvest	60 DAT	Harvest
T_1	Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})	1.97 ± 0.37^{b}	3.14 ± 0.96^{cd}	0.31 ± 0.06^{b}	0.54 ± 0.15^{cd}	2.47 ± 0.46^{b}	4.27 ± 1.21^{cd}
T_2	Florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})	1.92 ± 0.28^{b}	3.12 ± 0.38^{d}	0.30 ± 0.05^{b}	0.54 ± 0.04^{cd}	2.27 ± 0.31^{b}	4.29 ± 0.27^{cd}
T_3	Florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63+25) g ha^{-1})	2.03 ± 0.22^{b}	4.43 ± 0.79^{bc}	0.32 ± 0.05^{b}	0.69 ± 0.13^{bc}	2.53 ± 0.42^{b}	5.53 ± 0.99^{bc}
T_4	Penoxsulam 2.67% OD (25 g ha^{-1})	2.99 ± 0.51^{a}	5.12 ± 0.96^{b}	0.47 ± 0.08^{a}	0.80 ± 0.15^{ab}	3.73 ± 0.64^{a}	6.40 ± 1.20^{cd}
T_5	Cyhalofop-butyl 10.1% EC (80 g ha^{-1})	3.04 ± 0.16^{a}	5.39 ± 0.33^{ab}	0.48 ± 0.03^{a}	0.84 ± 0.05^{ab}	3.80 ± 0.20^{a}	6.73 ± 0.42^{ab}
T_6	Florpyrauxifen-benzyl 2.7% EC (31.25 g ha^{-1})	3.45 ± 0.82^{a}	6.24 ± 0.42^{a}	0.54 ± 0.13^{a}	0.98 ± 0.06^{a}	4.33 ± 0.99^{a}	7.80 ± 0.53^{a}
T_7	Hand weeding at 15 DAT and 30 DAT	1.55 ± 0.24^{b}	2.67 ± 0.67^{d}	0.24 ± 0.04^{b}	0.42 ± 0.10^{d}	1.93 ± 0.31^{b}	3.33 ± 0.83^{d}
T_8	Weedy check	9.12	15.09	1.42	2.36	11.40	18.86
SE m (±)		0.27	0.35	0.04	0.06	0.32	0.46
CD (p = 0.05)		0.820	1.080	0.130	0.180	0.990	1.430

Phosphorus removal by weeds

The treatment T_7 (hand weeding at 15 DAT and 30 DAT) resulted in lower phosphorus removal by weeds (0.24 ± 0.04 kg ha^{-1}) at 60 DAT. However, it was statistically at par with T_2 (0.30 ± 0.05 kg ha^{-1}), T_1 (0.31 ± 0.06 kg ha^{-1}) and T_3 (0.32 ± 0.05 kg ha^{-1}). Among the treatments, T_1 to T_7, phosphorus removal by weeds was noted to be comparatively higher and comparable in the treatments T_4 (0.47 ± 0.08 kg ha^{-1}), T_5 (0.48 ± 0.03 kg ha^{-1}), and T_6 (0.54 ± 0.13 kg ha^{-1}) (Table 3). Phosphorus removal by weeds observed at harvest stage showed that the treatments T_7 (hand weeding at 15 DAT and 30 DAT), T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})], and T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] resulted in comparatively lower values (0.42 ± 0.10 kg ha^{-1}, 0.54 ± 0.15 kg ha^{-1} and 0.54 ± 0.04 kg ha^{-1} respectively) and were statistically comparable. While the treatments, T_3 (0.69 ± 0.13 kg ha^{-1}), T_4 (0.80 ± 0.15 kg ha^{-1}), and T_5 (0.84 ± 0.05 kg ha^{-1}) were at par, the treatments T_4, T_5, and T_6 (0.98 ± 0.06 kg ha^{-1}) remained statistically comparable. Both at 60 DAT and at harvest stages, the treatment T_8 (weedy check) exhibited the highest values for phosphorus removal by weeds (1.42 kg ha^{-1} and 2.36 kg ha^{-1} respectively). Phosphorus removal by weeds followed almost similar trend as nitrogen removal across the treatments with T_8 revealed the highest P removal and, T_7 and T_2 the lowest. Phosphorus is relatively immobile in flooded soil, so early emerging weeds rapidly capture P through extensive root systems and mycorrhizal associations. Hand weeding removed these roots at two critical stages (15 DAT and 30 DAT), cutting off further P uptake and leaving more available P for rice (Saudy *et al.*, 2021; Gao *et al.*, 2022) [24, 5]. The herbicide mixtures by reducing weeds, similarly limited root proliferation and surface foraging for P, although dead roots initially remained *in situ* before decomposing, which might have slightly prolonged P immobilisation compared with hand weeding (Mounisha *et al.*, 2021; Uno *et al.*, 2021) [17, 26].

Potassium removal by weeds

At 60 DAT, potassium removal by weeds was observed to be significantly lower and statistically comparable in the treatments, T_7 (1.93 ± 0.31 kg ha^{-1}), T_2 (2.27 ± 0.31 kg ha^{-1}), T_1 (2.47 ± 0.46 kg ha^{-1}), and T_3 (2.53 ± 0.42 kg ha^{-1}). The treatments, T_4 (3.73 ± 0.64 kg ha^{-1}), T_5 (3.80 ± 0.20 kg ha^{-1}), and T_6 (4.33 ± 0.99 kg ha^{-1}) resulted in comparatively higher potassium removal by weeds (Table 3). At harvest, the treatments T_7, T_1 and T_2 resulted in comparatively lower and statistically comparable values for potassium removal by weeds (3.33 ± 0.83 kg ha^{-1}, 4.27 ± 1.21 kg ha^{-1}, and 4.29 ± 0.27 kg ha^{-1}, respectively). The treatments, T_2, T_3 (5.53 ± 0.99 kg ha^{-1}), and T_4 (6.40 ± 1.20 kg ha^{-1}) were statistically at par, the treatments. Among the treatments, T_1 to T_7, weeds exhibited comparatively higher potassium removal in T_5 (6.73 ± 0.42 kg ha^{-1}) and T_6 (7.80 ± 0.53 kg ha^{-1}), which were again statistically on a par. Weedy check (T_8) showed the highest values for potassium removal by weeds at 60 DAT (11.40 kg ha^{-1}) and at harvest (18.86 kg ha^{-1}) stages. Potassium removal by weeds was also markedly lower in herbicide treatments. It also followed the similar pattern as N and P removal. Since potassium uptake in weeds scales with total biomass and transpiration rate, early effective weed removal might have directly lowered K uptake, as suggested by Patel *et al.* (2023) [19] and Saikia *et al.* (2024)

[22]. The herbicide mixtures sharply reduced weed biomass and K uptake but dead weeds left on the soil surface may leach some K back or continue minimal uptake until full necrosis (Pratap *et al*., 2022) [20]. Padmaja and Ramprakash (2022) [18] also reported similar findings.

Effect on yield of rice

Grain yield

Hand weeding at 15 DAT and 30 DAT (T_7) resulted in higher grain yield (3618 ± 213 kg ha^{-1}) and remained statistically comparable *(*3559 ± 203 kg ha^{-1}*)* with T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})]. It was followed by T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})] and T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] which were at par (3165 ± 242 kg ha^{-1} and 3050 ± 144 kg ha^{-1} respectively). The treatments T_4 [penoxsulam 2.67% OD (25 g ha^{-1})], T_5 [cyhalofop-butyl 10.1% EC (80 g ha^{-1})], and T_6 [florpyrauxifen-benzyl 2.7% EC (31.25 g ha^{-1})], where in straight herbicides were tested yielded lower compared to the ready-mix herbicides and moreover their effect in terms of grain yield were on a par (Table 4). Florpyrauxifen-benzyl + cyhalofop-butyl mixture recorded 70.59 per cent increase in yield over weedy check yield and was comparable to the grain yield achieved under hand weeding. Similar findings were reported by Mahapatra *et al*. (2023) [12], and Padmaja and Ramprakash (2022) [18]. Venkatesh *et al*. (2020) [27] reported the broad-spectrum nature of the ready-mix herbicide also prevented the compensatory emergence of unsuppressed weeds, which could otherwise have negative impact on the late season yield advantages.

Weed index

Weed index varied significantly in response to the treatments (Table 4). The treatment T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] resulted in the lowest weed index (1.63%). It was followed by T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})] (12.5%) and T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] (15.64%) which were statistically at par. The treatments, T_4, T_5, and T_6 resulted in statistically similar values for weed index (21.69%, 21.64%, and 22.52% respectively). The lowest weed index of 1.63 per cent was recorded in florpyrauxifen-benzyl + cyhalofop-butyl, while the highest WI was observed in weedy check. The superior performance of florpyrauxifen-benzyl + cyhalofop-butyl could be attributed to the synergistic action of the herbicide mixture which effectively controlled all types of weed flora leading to reduced weed density and minimal yield loss (Sreedevi *et al*., 2020; Mahapatra *et al*., 2023) [25, 12]. In contrast, the high WI in weedy check reflects the absence of weed management practices resulting in intense weed competition and significant yield reduction.

Phosphorus removal by weeds

The treatment T_7 (hand weeding at 15 DAT and 30 DAT) resulted in lower phosphorus removal by weeds (0.24 ± 0.04 kg ha^{-1}) at 60 DAT. However, it was statistically at par with T_2 (0.30 ± 0.05 kg ha^{-1}), T_1 (0.31 ± 0.06 kg ha^{-1}) and T_3 (0.32 ± 0.05 kg ha^{-1}). Among the treatments, T_1 to T_7, phosphorus removal by weeds was noted to be comparatively higher and comparable in the treatments T_4 (0.47 ± 0.08 kg ha^{-1}), T_5 (0.48 ± 0.03 kg ha^{-1}), and T_6 (0.54 ± 0.13 kg ha^{-1}) (Table 3). Phosphorus removal by weeds observed at harvest stage showed that the treatments T_7 (hand weeding at 15 DAT and 30 DAT), T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})], and T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] resulted in comparatively lower values (0.42 ± 0.10 kg ha^{-1}, 0.54 ± 0.15 kg ha^{-1} and 0.54 ± 0.04 kg ha^{-1} respectively) and were statistically comparable. While the treatments, T_3 (0.69 ± 0.13 kg ha^{-1}), T_4 (0.80 ± 0.15 kg ha^{-1}), and T_5 (0.84 ± 0.05 kg ha^{-1}) were at par, the treatments T_4, T_5, and T_6 (0.98 ± 0.06 kg ha^{-1}) remained statistically comparable. Both at 60 DAT and at harvest stages, the treatment T_8 (weedy check) exhibited the highest values for phosphorus removal by weeds (1.42 kg ha^{-1} and 2.36 kg ha^{-1} respectively). Phosphorus removal by weeds followed almost similar trend as nitrogen removal across the treatments with T_8 revealed the highest P removal and, T_7 and T_2 the lowest. Phosphorus is relatively immobile in flooded soil, so early emerging weeds rapidly capture P through extensive root systems and mycorrhizal associations. Hand weeding removed these roots at two critical stages (15 DAT and 30 DAT), cutting off further P uptake and leaving more available P for rice (Saudy *et al*., 2021; Gao *et al*., 2022) [24, 5]. The herbicide mixtures by reducing weeds, similarly limited root proliferation and surface foraging for P, although dead roots initially remained *in situ* before decomposing, which might have slightly prolonged P immobilisation compared with hand weeding (Mounisha *et al*., 2021; Uno *et al*., 2021) [17, 26].

Potassium removal by weeds

At 60 DAT, potassium removal by weeds was observed to be significantly lower and statistically comparable in the treatments, T_7 (1.93 ± 0.31 kg ha^{-1}), T_2 (2.27 ± 0.31 kg ha^{-1}), T_1 (2.47 ± 0.46 kg ha^{-1}), and T_3 (2.53 ± 0.42 kg ha^{-1}). The treatments, T_4 (3.73 ± 0.64 kg ha^{-1}), T_5 (3.80 ± 0.20 kg ha^{-1}), and T_6 (4.33 ± 0.99 kg ha^{-1}) resulted in comparatively higher potassium removal by weeds (Table 3). At harvest, the treatments T_7, T_1 and T_2 resulted in comparatively lower and statistically comparable values for potassium removal by weeds (3.33 ± 0.83 kg ha^{-1}, 4.27 ± 1.21 kg ha^{-1}, and 4.29 ± 0.27 kg ha^{-1}, respectively). The treatments, T_2, T_3 (5.53 ± 0.99 kg ha^{-1}), and T_4 (6.40 ± 1.20 kg ha^{-1}) were statistically at par, the treatments. Among the treatments, T_1 to T_7, weeds exhibited comparatively higher potassium removal in T_5 (6.73 ± 0.42 kg ha^{-1}) and T_6 (7.80 ± 0.53 kg ha^{-1}), which were again statistically on a par. Weedy check (T_8) showed the highest values for potassium removal by weeds at 60 DAT (11.40 kg ha^{-1}) and at harvest (18.86 kg ha^{-1}) stages. Potassium removal by weeds was also markedly lower in herbicide treatments. It also followed the similar pattern as N and P removal. Since potassium uptake in weeds scales with total biomass and transpiration rate, early effective weed removal might have directly lowered K uptake, as suggested by Patel *et al*. (2023) [19] and Saikia *et al*. (2024) [22].

The herbicide mixtures sharply reduced weed biomass and K uptake but dead weeds left on the soil surface may leach some K back or continue minimal uptake until full necrosis (Pratap *et al*., 2022) [20]. Padmaja and Ramprakash (2022) [18] also reported similar findings.

Effect on yield of rice

Grain yield

Hand weeding at 15 DAT and 30 DAT (T_7) resulted in higher grain yield (3618 ± 213 kg ha^{-1}) and remained statistically comparable *(*3559 ± 203 kg ha^{-1}*)* with T_2 [florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})]. It was followed by T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})] and T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] which were at

par (3165 ± 242 kg ha^{-1} and 3050 ± 144 kg ha^{-1} respectively). The treatments T_4 [penoxsulam 2.67% OD (25 g ha^{-1})], T_5 [cyhalofop-butyl 10.1% EC (80 g ha^{-1})], and T_6 [florpyrauxifen-benzyl 2.7% EC (31.25 g ha^{-1})], where in straight herbicides were tested yielded lower compared to the ready-mix herbicides and moreover their effect in terms of grain yield were on a par (Table 4). Florpyrauxifen-benzyl + cyhalofop-butyl mixture recorded 70.59 per cent increase in yield over weedy check yield and was comparable to the grain yield achieved under hand weeding. Similar findings were reported by Mahapatra *et al*. (2023) [12], and Padmaja and Ramprakash (2022) [18]. Venkatesh *et al*. (2020) [27] reported the broad-spectrum nature of the ready-mix herbicide also prevented the compensatory emergence of unsuppressed weeds, which could otherwise have negative impact on the late season yield advantages.

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Table 4: Effect of straight and ready-mix herbicides on grain yield and weed index in transplanted rice.

Treatment		Grain yield (kg ha^{-1})	Weed index (%)
T_1	Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})	3165 ± 242^b	12.52
T_2	Florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})	3559 ± 203^a	1.63
T_3	Florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})	3050 ± 144^b	15.69
T_4	Penoxsulam 2.67% OD (25 g ha^{-1})	2833± 55^c	21.69
T_5	Cyhalofop-butyl 10.1% EC (80 g ha^{-1})	2835 ± 95^c	21.64
T_6	Florpyrauxifen-benzyl 2.7% EC (31.25 g ha^{-1})	2803 ± 92^c	22.52
T_7	Hand weeding at 15 DAT and 30 DAT	3618± 213^a	-
T_8	Weedy check	1064	70.59
SE m (±)		58	-
CD (p = 0.05)		180.1	-

Table 5: Effect of straight and ready-mix herbicides on gross income, net income and B:C ratio in transplanted rice.

Treatment		Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio
T_1	Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})	132452	30798	1.30
T_2	Florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})	148787	45640	1.44
T_3	Florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})	128332	26231	1.26
T_4	Penoxsulam 2.67% OD (25 g ha^{-1})	119315	18956	1.19
T_5	Cyhalofop-butyl 10.1% EC (80 g ha^{-1})	119237	19205	1.19
T_6	Florpyrauxifen-benzyl 2.7% EC (31.25 g ha^{-1})	118137	14351	1.14
T_7	Hand weeding at 15 DAT and 30 DAT	151925	26356	1.21
T_8	Unweeded control (weedy check)	48763	-28806	0.63

Economics

Gross income was observed to be higher (₹ 151925 ha^{-1}) in T_7 (hand weeding at 15 DAT and 30 DAT) and it was followed by T_2 [(florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})] (₹ 130990 ha^{-1}), T_1 [penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (135 g ha^{-1})] (₹ 132452 ha^{-1}), and T_3 [florpyrauxifen-benzyl 1.31% w/w + penoxsulam 2.1% w/w OD (15.63 + 25) g ha^{-1})] (₹ 128332 ha^{-1}). Gross income was comparatively lower in the treatments T_4 (₹ 119315 ha^{-1}), T_5 (₹ 119237 ha^{-1}) and T_6 (₹ 118137 ha^{-1}). Weedy check (T_8) resulted in the lowest gross income (₹ 48763 ha^{-1}). However, the highest net income (₹ 45640 ha^{-1}) and B:C ratio (1.44) was observed in T_2 [(florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1})]. The net income was followed by T_1, T_7, and T_3 and B:C ratio followed by T_1, T_3, and T_7 (Table 5). The improved economic returns of treatment T_2 were mostly attributable to increased grain yield and lower labour costs because of successful weed control. Similar findings were reported by Sreedevi *et at.* (2023) [25], Venkatesh *et al.* (2020) [27] and Rizal and Arbiwati (2024) [21].

4. Conclusion

From the study it could be inferred that early post-emergence application of the ready-mix herbicide, florpyrauxifen-benzyl 2.13% w/w + cyhalofop-butyl 10.64% w/w EC (150 g ha^{-1}) at 15 DAT was as effective as the conventional practice (two hand weedings at 15 DAT and 30 DAT) in managing weeds in transplanted rice. It consistently reduced the weed density, weed dry weight, weed persistence and nutrient removal by weeds, while improving crop yield and profitability.

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