

Multilocal Evaluation of Early Post-emergence Herbicide Application on Weed Control, Yield and Economics of Transplanted Rice (*Oryza sativa* L.) through Front-line Demonstration

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ABSTRACT

Climate change provides substantial problems to world agriculture, especially for key crops like rice (*Oryza sativa* L.). Rising temperatures, variable rainfall, and altered weed dynamics have made crop-weed competition more intense, demanding better weed management measures. Weeds severely lower rice yields by competing for key resources, and hand weeding is both labour-intensive and inefficient. Early post-emergence herbicide spraying has emerged as a viable option, delivering excellent weed control while improving crop development and production. Hence considering the following a frontline demonstration was conducted at farmers' field of Puri, Sundargarh and Bolangir district of Odisha during *kharif* 2023 to compare demonstration of Post emergence application of Cyhalofop butyl + Penoxulam @ 135 g ai/ha at 20 DAT with farmers practice of pre emergence application of Pretrilachlor @ 0.5 kg ai/ha, where, the demonstration treatment recorded highest ear bearing tillers (340 nos. /m² in Puri; 348 nos. /m² in Sundargarh and 346 nos. /m² in Bolangir district), grains per panicle (124 nos. in Puri; 122 nos. in Sundargarh and 122 nos. in Bolangir district), grain yield (43.3 q/ha in Puri; 44.2 q/ha in Sundargarh and 44.1 q/ha in Bolangir district) and benefit cost ration (1.78 in Puri; 1.79 in Sundargarh and 1.77 in Bolangir district).

Keywords: Climate change, Frontline demonstration, Cyhalofop butyl, Penoxulam, rice, Weed management practices, Yield

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Climate change is a significant global concern that impacts agricultural production systems worldwide (Mondal *et al.* 2021; Ray *et al.* 2024; Pattanayak *et al.* 2025a,b). Rising temperatures, irregular rainfall patterns, increased frequency of extreme weather events, and alterations in pest and weed dynamics pose threats to global food security (Maitra *et al.* 2024a; Krishna *et al.* 2024). Additionally the intensive and cereal based agriculture not only deteriorates the soil and environment (Ghosh *et al.* 2021; Ray *et al.* 2025; Palai *et al.* 2021) but also increases pest, disease and weed incidence (Maitra *et al.* 2020; Manasa *et al.* 2020; Zahan *et al.* 2021). Rice, being a staple crop critical to global food security, is sensitive to climate change (Maitra and Zaman, 2017; Sharma *et al.* 2020; Kundu *et al.* 2020; Ghosh *et al.* 2021; Ghosh *et al.* 2024; Hemasree *et al.* 2025). India, the primary engine of the Indian economy, accounts for approximately 19% of the Gross Domestic Product (GDP) (GoI, 2023) and sustains a significant portion of its population (Santosh and Maitra 2021). Rice contributes around 10% to the agricultural GDP and creates 3.5 billion days of employment in India (Fageria 2007; Pathak *et al.* 2020). However, rice productivity in India is relatively low, with weeds being a major limiting factor. Studies show that weed infestations in transplanted rice can cause yield reductions between 27% and 68%. (Duary *et al.* 2015, Hossain and Malik 2017). The increasing prevalence of certain vegetatively propagating weeds, such as *Echinochloa crusgalli* and *E. colona*, are becoming significant threats in numerous rice cultivation areas in Eastern India (Maitra *et al.* 2024b). Issues such as labor shortages, escalating wages, and lack of effective weed control methods have led farmers to seek alternative strategies for managing weeds. Herbicides have emerged as the preferred solution for many (Palai *et al.* 2024), leading to a marked rise in their application throughout India (Sairam *et al.* 2023; Santosh *et al.* 2023). However, most herbicides are selective, affecting only a narrow spectrum of weed species, which can lead to several long-term complications.

Currently, herbicides recommended for use in transplanted rice, including Butachlor, Pretilachlor, Anilofos, and Oxadiargyl, are mainly applied before the emergence of crops. However, their effectiveness is often diminished, especially in conditions of water scarcity right after transplanting.

This situation underscores the urgent requirement for post-emergence herbicides to effectively manage the complex weed populations in transplanted rice. A novel ready-mix PoE herbicide, consisting of Penoxsulam at 1.02% w/w (1.0% w/v) and Cyhalofop-butyl at 5.1% w/w (5.0% w/v), has been developed for effective weed management in transplanted rice. (Mishra *et al.* 2007, Yadav *et al.* 2008). Typically, utilizing a single application of a premix or tank-mix of herbicides, whether applied before or after emergence, is a more cost-effective strategy for effective weed control. The application of post-emergence (PoE) combinations is often favoured over pre-emergence (PE) treatments, as it allows for the selection of appropriate herbicides based on the specific weed species affecting the crop. A novel ready-mix PoE herbicide, consisting of Penoxsulam at 1.02% w/w (1.0% w/v) and Cyhalofop-butyl at 5.1% w/w (5.0% w/v), has been developed for effective weed management in transplanted rice (Kailkhura *et al.* 2015, Singh *et al.* 2016, Hossain and Malik, 2017). While the recommended herbicides, Penoxsulam and Bispyribac-sodium, are effective against *Echinochloa* and a few broadleaf weeds and sedges, the increasing occurrence of other aerobic grassy weeds, such as *Leptochloa chinensis* and various *Eragrostis* species, especially in conditions of water scarcity, calls for an enhanced weed management strategy. Therefore, there is an urgent need to develop effective and economically viable weed management technologies to promote sustainable rice farming in lowland ecosystems as because proper weed management not only increases crop yield but also leads to better resource optimization (Maitra *et al.* 2001). There is an urgent need to develop effective and economically viable weed management technologies to promote sustainable rice farming in lowland ecosystems and one such solution is frontline demonstration (FLD). FLDs are an important technique for evaluating novel agronomic approaches, including the use of herbicides in weed management. FLDs are used to evaluate novel agricultural technology in real-world settings and encourage their adoption by farmers. The use of early post-emergence herbicides in rice production via FLDs contributes to their efficacy in weed control, crop yield enhancement, and economic returns. The fundamental goal of such demonstrations is to give farmers with scientific validation and practical proof about the

possible advantages of herbicide use while taking into account environmental sustainability. Hence, this paper emphasises on Evaluation of early post-emergence herbicide application on weed control, crop yield and economics of transplanted rice (*Oryza sativa* L.) through front line demonstration.

MATERIALS AND METHODS

A front-line demonstration was carried out on 30 farmers' fields across six villages namely, Basudeipur and Kahnapur in Puri district; Phuldhudi and Sahebdera in Sundargarh district, Badgaon and Odiapali of Bolangir district in Odisha. The demonstration focused on the post-emergence application of Cyhalofop butyl and Penoxulam at a rate of 135 g ai/ha, applied at 20 days after transplanting (DAT) as Technology-2. In contrast, Technology-1 involved the farmers' traditional practice of pre-emergence application of Pretilachlor at 0.5 kg ai/ha during the *kharif* season of 2023. The herbicides were administered using a knapsack sprayer equipped with a flat fan nozzle. A fertilizer mix of 80:40:40 N:P₂O₅:K₂O kg/ha was applied, alongside other agronomic practices throughout the crop season. At maturity, plant height was measured from 10 randomly selected plants. Weed assessments were conducted using a 0.5 m² quadrant at 30 days after application (DAA), with weed dry weight determined after drying samples in an oven at 70°C for 72 hours. Weed control efficiency (WCE) was calculated using the following formula:

$$WCE \% = \frac{(\text{Weed count in the not weeded plot} - \text{weed count in treated plot})}{\text{weed count in not weeded plot}} \times 100$$

The crop was harvested from a net plot area of 6 m² and extrapolated to a hectare. For economic analysis, total costs (both variable and fixed) were calculated based on current input prices. Gross returns were determined by multiplying the yield by the prevailing market price, with net benefits calculated by subtracting total costs from gross returns. To raise awareness and encourage the adoption of this technology, training sessions and field days were organized for both farmers and farm women. Additionally, leaflets and pamphlets outlining improved Paddy cultivation practices were distributed, along with regular field visits and timely technical support. The effectiveness of

these initiatives was evaluated by calculating the technology gap, extension gap, and technology index, following the methodology established by Samui *et al.* (2000).

$$\text{Net return (₹ ha}^{-1}\text{)} = \text{Gross cost (₹ ha}^{-1}\text{)} - \text{Cost of cultivation (₹ ha}^{-1}\text{)}$$

$$B:C \text{ ratio} = \frac{\text{Net income (Rs.ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs.ha}^{-1}\text{)}}$$

$$\text{Extension gap} = \text{Demonstration yield} - \text{Yield under Farmers Practices}$$

$$\text{Technology gap} = \text{Potential Yield} - \text{Demonstration Yield}$$

Pooja (CR -629-256) developed from parentage Vijaya × T 141 at CRRI, Cuttack in the year 1999. It is an improved late duration (150 days) popular variety of paddy released by CVRC in the year 2009 for cultivation in shallow lowland area of Odisha, Assam, Madhya Pradesh and West Bengal. It has medium slender grains with an average yield of 5.0 t ha⁻¹ and have excellent cooking quality. It possesses field tolerance to all major diseases and pests. It can tolerate water stagnation (up to 25 cm) and suitable for late transplanting with aged seedling. Days to 50% flowering 125 days.

RESULTS AND DISCUSSION

Weed Parameters

Major weed flora in field condition (Table 1) consisted of grasses, viz *Echinochloa colona* (L.) Link, *Echinochloa crusgalli* (L.) Beauv, *Leptochloa chinensis* (L.) Nees, *Paspalum distichum* (L.), Sedges, *Cyperus iria* (L.), *Cyperus difformis* (L.), *Fimbristylis miliacea* (L.) Vahl, broad leave weeds, viz. *Eclipta alba* (L.) Hassk, *Alternanthera philoxeroides* (Mart.) Griseb, *Aeschynomene indica* (L.), *Ammannia baccifera* (L.), *Sphenoclea zeylanica*, *Monochoria vaginallis* and *Marselia quadrifolia*. Similar reports have also been reported by earlier studies of Parthipan and Ravi (2016), Ramesha *et al.* (2017) and Dhanapal *et al.* (2018).

Post emergence application of Cyhalofop butyl + Penoxulam @ 135g ai/ha at 20 DAT recorded a 28.2 % higher weed control in Puri district; 30.6 % higher weed control in Sundargarh district and 30.3 % higher weed control in Bolangir district over

Table 1: Weed flora found in the demonstration area with common name, botanical name and family

Botanical Name	Family	Common Name
Grasses		
<i>Echinochloa colona</i> (L.) Link	Poaceae	Jungle rice
<i>Echinochloa crusgalli</i> (L.) Beauv	Poaceae	barnyard grass
<i>Leptochloa chinensis</i> (L.) Nees	Poaceae	Red sprangle top
<i>Paspalum distichum</i> (L.)	Poaceae	Knot grass
Sedges		
<i>Cyperus iria</i> (L.)	Cypereaceae	Rice flat sedge
<i>Cyperus difformis</i> (L.)	Cypereaceae	Rice sedge
<i>Fimbristylis miliacea</i> (L.) Vahl	Cypereaceae	Grass like Fimbry
Broad leave weeds		
<i>Eclipta alba</i> (L.) Hassk	Asteraceae	Bhringraj
<i>Alternanthera philoxeroids</i> (Mart.) Griseb	Amaranthaceae	Alligator weed
<i>Aeschynomene indica</i> (L.)	Fabaceae	Indian joint vetch
<i>Ammannia baccifera</i> (L.)	Lythraceae	Monarch redstem
<i>Sphenoclea zeylanica</i>	Sphenocleaceae	Wedge wort
<i>Monochoria vaginalis</i> (Burm.f.) C.Presl	Pontederiaceae	Pickernel Weed
<i>Marselia quadrifolia</i> .	Maesileaceae	European water clover

the farmer's practice at 30 DAA. Similar report of higher weed control efficiency due to application of post emergence application of Cyhalofop butyl + Penoxulam @ 135g ai/ha has also been reported by Srinithan *et al.* (2021).

Yield parameters and yield

Demonstration plot with post emergence application of Cyhalofop butyl + Penoxulam @ 135g ai/ha at 20 DAT recorded higher ear bearing tiller (340 nos. /m² in Puri; 348 nos. /m² in Sundargarh and 346 nos. /m² in Bolangir district), grains per panicle (124 nos. in Puri; 122 nos. in Sundargarh and 122 nos. in Bolangir district) and grain yield (43.3 q/ha in Puri; q/ha in Sundargarh and 44.1 q/ha in Bolangir district) over farmers practice with pre-emergence application of Pretilachlor @ 0.5 kg ai/ha (Table 2 and Fig. 1). The post emergence application of a premix formulation containing penoxsulam and cyhalofop butyl at a rate of 135 g ha⁻¹ (20 days after transplanting) significantly enhances weed control efficiency. This improvement can be attributed to penoxsulam's potent inhibition of the enzyme acetolactate synthase (ALS), which disrupts the synthesis of essential amino acids such as valine, leucine, and isoleucine, ultimately leading to weed death by interfering with protein production

(WSSA, 2007). Additionally, cyhalofop butyl serves as a selective post-emergence herbicide targeting grassy weeds in rice by inhibiting the enzyme Acetyl-Coenzyme A Carboxylase (ACCase), which is crucial for fatty acid biosynthesis (Santaella-Ruiz *et al.* 2006). The synergistic effect of the penoxsulam and cyhalofop butyl combination provides a broad spectrum of herbicidal activity against various weeds in the rice ecosystem, resulting in improved weed control effectiveness, as evidenced by reduced weed metrics and enhanced control efficiency. This observation aligns with the findings of Abraham and Menon (2015) and Srinithan *et al.* (2021).

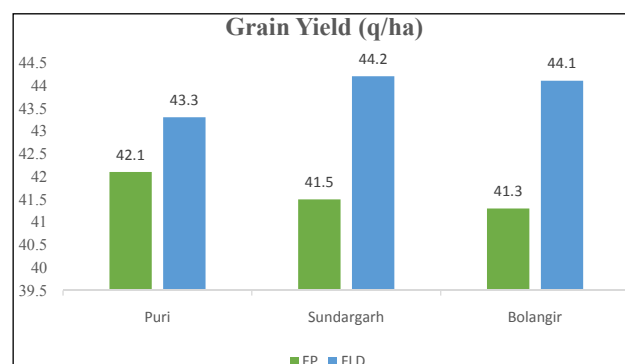

Fig. 1: Difference between farmers practice and FLD at multilocation for grain yield of Rice

Table 2: Yield attributing characters and % Weed Control over FP as affected by weed management practices in the front-line demonstration

Treatments	% Weed Control over FP			EBT/m ² (No.)			Panicle Length (cm)			Grains/ panicle (No.)		
	Puri	Sundargarh	Bolangir	Puri	Sundargarh	Bolangir	Puri	Sundargarh	Bolangir	Puri	Sundargarh	Bolangir
FP	—	—	—	308	320	315	22.1	22.0	22.2	108	103	102
FLD	28.2	30.6	30.3	340	348	346	22.4	22.3	22.4	124	122	122

FP: Pre emergence application of Pretilachlor @ 0.5 kg ai/ha, FLD: Post emergence application of Cyhalofop butyl + Penoxulam @ 135g ai/ha at 20 DAT.

Table 3: Yield and economics as affected by weed management practices in the front-line demonstration

Treatments	Grain yield (q/ha)			Net Return (₹/ha)			B:C Ratio		
	Puri	Sundargarh	Bolangir	Puri	Sundargarh	Bolangir	Puri	Sundargarh	Bolangir
FP	42.1	41.5	41.3	38904	36306	37757	1.73	1.69	1.70
FLD	43.3	44.2	44.1	41524	44649	43653	1.78	1.79	1.77

FP: Pre emergence application of Pretilachlor @ 0.5 kg ai/ha, FLD: Post emergence application of Cyhalofop butyl + Penoxulam @ 135g ai/ha at 20 DAT.

Economics

Front line demonstration on post emergence application of Cyhalofop butyl + Penoxulam @ 135g ai/ha at 20 DAT recorded higher net return and benefit cost ratio of ₹ 41524/ha and 1.78 in Puri district; ₹ 44649/ha and 1.79 in Sundargarh district and ₹ 43653/ha and 1.77 in Bolangir district of Odisha over farmers practices of pre-emergence application of Pretilachlor @ 0.5 kg ai/ha for the respective values of ₹ 38904/ha and 1.73 in Puri district; ₹ 36306/ha and 1.69 in Sundargarh district and ₹ 37757/ha and 1.70 in Bolangir district of Odisha (Table 3) which aligned with findings of Kumar *et al.* 2018.

Extension Gap

The extension gap refers to the disparity in yield between demonstration plots and the practices employed by farmers, which was measured at 1.2 q/ha in Puri district; 2.7 q/ha in Sundargarh district and 2.8 q/ha in Bolangir district of Odisha. This gap underscores the necessity for enhanced technology transfer and education for farmers. The superior yields observed in demonstration plots indicate that it is crucial for farmers to adopt improved high-yielding varieties and agricultural technologies. Encouraging farmers to embrace these new high-yielding varieties and better crop management

practices could significantly mitigate the troubling trend of an expanding extension gap.

Technology Gap

The technology gap represents the difference between the yield achieved in demonstration plots and the potential yield. The recorded technology gap was 6.7 q/ha in Puri district; 5.8 q/ha in Sundargarh district and 5.9 q/ha in Bolangir district of Odisha. This gap may be attributed to variations in soil fertility and weather conditions (Mandavkar *et al.* 2012).

Technology Index

The technology index assesses the practicality of the technology in farmers' fields. A lower technology index value indicates greater feasibility. The technology index was found to be 13.4% in Puri district; 11.6% in Sundargarh district and 11.8% in Bolangir district of Odisha.

CONCLUSION

Climate change has a profound impact on worldwide rice production, impacting weed dynamics, pesticide efficacy, and total crop yield. Rising temperatures, irregular rainfall patterns, and rising atmospheric CO₂ levels impact weed-crop competition, favoring

more aggressive and herbicide-resistant weeds. The results revealed that the FLD program serves as an effective mechanism for enhancing both the production and productivity of rice. Additionally, it plays a crucial role in improving farmers' knowledge, attitudes, and skills. This initiative has contributed not only to socio-economic stability but has also been vital in achieving food and nutrition security within the community. However, in periods of labor shortages and increased labor costs, an post-emergence application of a premix formulation containing penoxsulam and cyhalofop butyl at a rate of 135 g ha⁻¹ (20 days after transplanting) may serve as an effective alternative for weed management in transplanted rice. This significant improvement raised awareness and encouraged other farmers to adopt enhanced rice cultivation practices. Furthermore, this demonstration fostered a stronger relationship and built trust between farmers and KVK scientists.

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