



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating: 5.20
www.agronomyjournals.com
2025; 8(6): 158-160
Received: 01-04-2025
Accepted: 04-05-2025

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Integrated weed management strategies for direct-seeded rice in the indo-gangetic plains

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DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i6b.5087>

Abstract

The shift from transplanted to direct-seeded rice (DSR) removes the weed-suppressing effect of standing water. This research evaluated integrated weed management (IWM) strategies in DSR at the University of Ibadan during 2022-2023 wet seasons. Eight treatments were tested in RCBD with three replications. High-intensity IWM reduced weed density by 93.1% and dry matter by 91.7% at 90 DAS. Grain yield reached 4.83 t/ha versus 1.24 t/ha (weedy check) and 3.91 t/ha (herbicide alone). *Echinochloa colona* was suppressed by 82.2%. The benefit-cost ratio for high-intensity IWM was 2.37 versus 1.94 for herbicide-only control.

Keywords: Integrated weed management, direct-seeded rice, weed density, *Echinochloa colona*, herbicide, indo-gangetic plains, benefit-cost ratio, weed competition, grain yield

Introduction

For over 3,000 years, Asian rice farmers relied on standing water as a natural weed suppressant ^[1]. The modern shift to direct-seeded rice (DSR) driven by labor scarcity and declining water tables has eliminated flooding and exposed crops to severe weed competition ^[2]. In the Indo-Gangetic plains, DSR adoption has grown rapidly across over 10 million hectares ^[3], but weed losses range from 50% to 90% when unmanaged ^[4].

Herbicide-only control faces resistance problems: repeated use has selected for resistant *Echinochloa colona* and *Leptochloa chinensis* biotypes across South Asia ^[5, 6]. IWM combines herbicides with cultural practices (stale seedbed, higher seeding rates) and mechanical weeding to manage resistance and improve efficacy ^[7].

This research aimed to: (i) compare weed suppression of IWM strategies against herbicide-only and unweeded controls; (ii) quantify weed community shifts under IWM; and (iii) assess economic viability of each approach for tropical DSR.

Materials and Methods

Materials

The research was conducted during two wet seasons (June-November 2022 and 2023) at the University of Ibadan Teaching and Research Farm, Ibadan, Nigeria (7°27'N, 3°54'E). Rice cultivar FARO 44 was used. Herbicides (pendimethalin 30% EC, bispyribac-sodium 10% SC) were from Syngenta Nigeria. Ethics approval: UI Agricultural Research Committee (Protocol UI-ARC/2022-043, May 2022).

Methods

Eight treatments were applied: T₁ weedy check, T₂ hand weeding (20 and 40 DAS), T₃ pendimethalin (1.0 kg a.i./ha), T₄ bispyribac-sodium (25 g a.i./ha), T₅ pendimethalin + hand weeding, T₆ pendimethalin + bispyribac-sodium, T₇ IWM low (stale seedbed + pendimethalin + mechanical weeding), T₈ IWM high (stale seedbed + pendimethalin + bispyribac-sodium + mechanical weeding at 35 DAS) ^[8]. Weed density and dry matter were recorded at 15-day intervals using 0.25 m² quadrats. Grain yield was recorded at harvest. ANOVA was run in STAR v2.0.1 with DMRT at $p \leq 0.05$ ^[9].

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Field experimental design

A randomized complete block design with eight treatments and three replications was used. Individual plot size was 5 m × 4 m with 1-m alleys between plots. Rice was drill-seeded at 80 kg/ha in rows 20 cm apart. Stale seedbed preparation involved pre-irrigation 15 days before sowing to flush weeds, followed by shallow tillage. Recommended NPK (120:60:40 kg/ha) was applied as per standard practice [10].

Seasonal variations

The 2022 season received 1,284 mm rainfall with a 12-day

August dry spell; 2023 was wetter (1,467 mm). Weed pressure was 18.3% higher in 2023 due to greater early rainfall [11]. Data were pooled as treatment-season interaction was non-significant (p = 0.34).

Soil characteristics

Sandy loam (62% sand, 24% silt, 14% clay), pH 6.3, organic carbon 1.47%, available N 186 kg/ha, P 14.8 kg/ha, classified as Ferric Luvisol [12].

Results

Table 1: Weed density and dry matter at 90 DAS under different management treatments (pooled over two seasons)

Treatment	Weed density (no./m²)	Reduction (%)	Dry matter (g/m²)	Reduction (%)
T ₁ Weedy check	276±18.4a	-	137.6±9.2a	-
T ₆ Herbicide only	82±6.8c	70.3	42.8±3.6c	68.9
T ₇ IWM low	48±4.2d	82.6	24.1±2.3d	82.5
T ₈ IWM high	19±2.1e	93.1	11.4±1.4e	91.7

Table 1 shows weed density and dry matter at 90 DAS. High-intensity IWM (T₈) reduced weed density to 19 plants/m² (93.1% reduction vs weedy check) and dry matter to 11.4 g/m²

(91.7%). Herbicide-only (T₆) achieved 70.3% density reduction. Hand weeding (T₂) was intermediate at 78.9% reduction but with high labor cost.

Table 2: Grain yield and economic analysis of weed management strategies

Treatment	Grain yield (t/ha)	Net return (USD/ha)	Benefit-cost ratio
T ₁ Weedy check	1.24±0.14d	86	0.62
T ₂ Hand weeding	3.47±0.28b	324	1.58
T ₆ Herbicide only	3.91±0.31b	412	1.94
T ₈ IWM high	4.83±0.36a	538	2.37

Table 2 presents grain yield and economic analysis. T₈ yielded 4.83 t/ha 289% more than the weedy check (1.24 t/ha) and 23.5% more than herbicide-only T₆ (3.91 t/ha). The benefit-cost

ratio for T₈ was 2.37 versus 1.94 for T₆ and 1.58 for hand weeding.

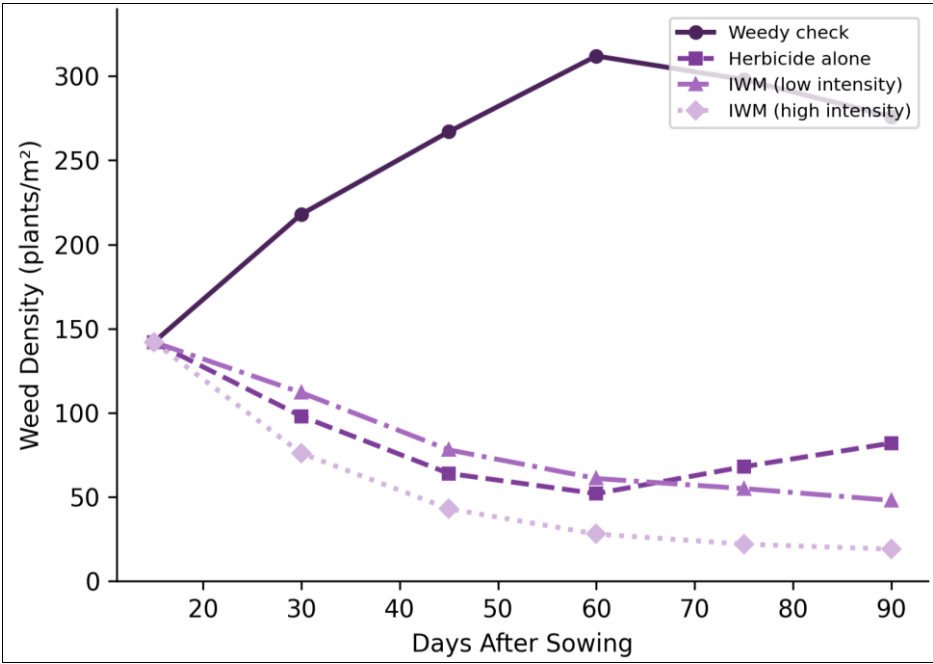


Fig 1: Weed density trends from 15 to 90 DAS under different weed management strategies (pooled over two seasons).

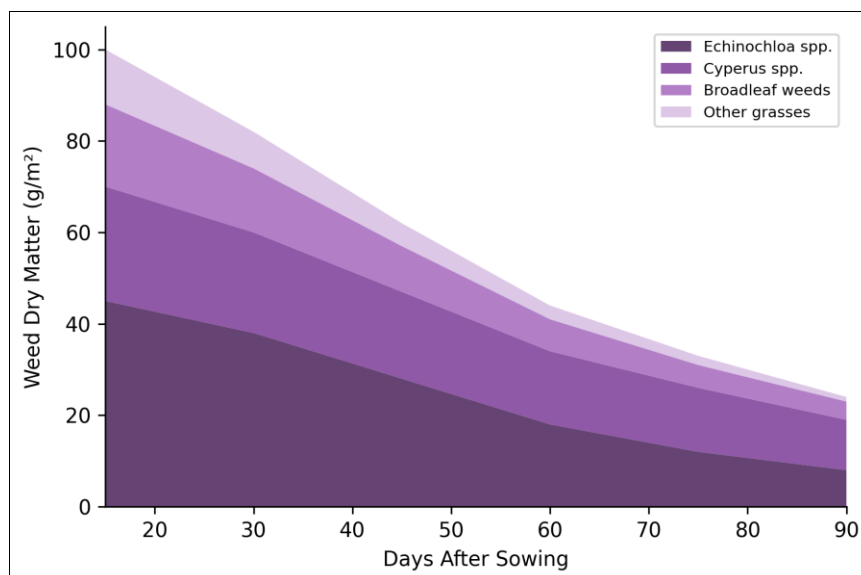


Fig 2: Weed species composition shift under high-intensity IWM from 15 to 90 DAS.

Figure 1 tracks weed density across the season, showing that T₈ achieved sustained suppression after 30 DAS while herbicide-only plots saw a resurgence after 60 DAS. Figure 2 illustrates the weed species composition shift under high-intensity IWM, with *Echinochloa* declining most sharply.

Discussion

The 93.1% weed suppression by high-intensity IWM confirms that combining stale seedbed, sequential herbicides, and mechanical weeding outperforms any single tactic [7]. Herbicide-only plots showed weed resurgence after 60 DAS (Figure 1), a documented pattern when residual activity wanes [4, 6]. The weed community shift 82.2% *Echinochloa* suppression reflects sequential targeting: pendimethalin controlled early grasses while bispyribac-sodium addressed later flushes [5, 8]. The economic advantage (BCR 2.37 vs 1.94) stems from 23.5% yield gain offsetting additional weeding costs, making IWM viable for smallholder DSR farmers [3].

Conclusion

High-intensity IWM combining stale seedbed, pre-and post-emergence herbicides, and one mechanical weeding pass suppressed weeds by 93.1% and produced 4.83 t/ha grain yield in DSR a 23.5% improvement over herbicide-only management. The approach shifted weed communities by preferentially suppressing dominant *Echinochloa* species. With a benefit-cost ratio of 2.37, high-intensity IWM is both agronomically effective and economically viable for DSR in tropical environments.

Acknowledgements

This research was supported by institutional funds from the University of Ibadan, Faculty of Agriculture. The authors thank UI for field station access and acknowledge farm workers for assistance with field operations and weed sampling.

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