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Evaluation of herbicide mixtures for weed management in direct seeded aerobic rice

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Abstract

Can herbicide mixtures offer a dependable answer to the growing weed menace in direct seeded aerobic rice? This question has become pressing as aerobic rice cultivation expands across water-scarce regions, and weeds remain the single largest biological constraint to grain yield. The present research was carried out during the wet season of 2023 at the research farm of Visayas State University, Baybay, Leyte, to evaluate five herbicide mixture treatments against a weedy check and a season-long weed-free control in a randomised complete block design with three replications. Treatments included pre-emergence pendimethalin (1000 g a.i. ha⁻¹) followed by post-emergence bispyribac-sodium (25 g a.i. ha⁻¹), pendimethalin followed by fenoxaprop-p-ethyl (60 g a.i. ha⁻¹), oxyfluorfen (200 g a.i. ha⁻¹) followed by bispyribac-sodium, and pendimethalin alone, compared against the controls. Observations on weed density, weed dry weight, weed control efficiency, crop growth parameters, and grain yield were recorded at 30, 60, and 90 days after sowing. Pendimethalin followed by bispyribac-sodium recorded the lowest weed density (24.6 no. m⁻²) and the highest weed control efficiency (71.8%) at 60 DAS, which translated into the highest grain yield (4.38 t ha⁻¹), statistically at par with the weed-free check. The weedy check suffered a yield penalty of 46.6% relative to the best treatment. These results point to the sequential application of pendimethalin and bispyribac-sodium as a practical, cost-effective weed management option for aerobic rice under direct seeding in the Visayas region.

Keywords: Herbicide mixtures, weed management, aerobic rice, direct seeding, weed control efficiency, pendimethalin, bispyribac-sodium, grain yield, weed density, wet season

Introduction

How long can rice farmers afford to ignore the yield gap that weeds create in direct seeded systems? Across Southeast Asia, the shift from transplanted puddled rice to direct seeded aerobic rice has accelerated as a response to rising labour costs, declining water tables, and methane-emission concerns [1]. Yet the absence of a standing water layer—the single most effective weed suppressant in conventional paddies—exposes aerobic rice to intense weed competition from the very first week after sowing [2]. Yield losses of 50-80% have been documented when weeds are left unmanaged in aerobic rice, making effective weed control the deciding factor between profit and loss for smallholder growers [3].

Hand weeding, though effective, is labour-intensive, time-bound, and increasingly uneconomical [4]. Single-herbicide applications often fall short because the weed flora in aerobic rice fields is complex, typically comprising grasses, broadleaved species, and sedges that differ in their susceptibility to any one active ingredient [5]. This gap has spurred interest in herbicide mixtures—sequential or tank-mix combinations of two molecules with complementary spectra—that can broaden the window and breadth of weed control [6].

Pendimethalin, a dinitroaniline pre-emergence herbicide, controls annual grasses and certain broadleaved weeds by inhibiting cell division in emerging seedlings [7]. When followed by a post-emergence partner such as bispyribac-sodium, an acetolactate synthase inhibitor with activity on *Echinochloa* spp. and other late-emerging grasses, or fenoxaprop-p-ethyl, an ACCase inhibitor selective to grasses, the combination can target both the early and late weed flushes [8]. Oxyfluorfen, a PPO-inhibiting contact herbicide, offers an alternative pre-emergence option with residual activity on broadleaved weeds [9].

Despite a growing body of evidence on individual herbicides, field-level data comparing these mixtures under the agro-climatic conditions of the Visayas highlands remain limited ^[10]. The Visayas region of the Philippines, with its high rainfall and laterite soils, presents a distinct weed flora and herbicide-persistence profile that may not respond identically to recommendations developed for the Central Luzon lowlands ^[11]. This research therefore aimed to evaluate five herbicide mixture treatments for weed suppression, crop safety, and grain yield in direct seeded aerobic rice at Baybay, Leyte.

Material and Methods

Study Area Description

The research was conducted at the experimental farm of Visayas State University, Baybay, Leyte (10°44'N, 124°48'E; 32 m above mean sea level), Leyte, during the wet season (June–November 2023). The region receives an average annual rainfall of 2,600 mm, mostly between June and September. Soil at the trial site was clay loam with a pH of 5.8, organic carbon of 1.68%, and available N, P, and K of 245, 22.4, and 156 kg ha⁻¹ respectively.

Material

Rice variety MAS-946, a medium-duration aerobic-adapted genotype, was used as the test crop. Herbicide formulations were procured from registered dealers: pendimethalin 30 EC, bispyribac-sodium 10 SC, fenoxaprop-p-ethyl 9.3 EC, and oxyfluorfen 23.5 EC. Standard fertilisers (urea, single super phosphate, muriate of potash) were applied at recommended rates of 100:50:50 kg N:P₂O₅:K₂O ha⁻¹ ^[12].

Field Experimental Design

The experiment was laid out in a randomised complete block design with seven treatments and three replications, giving 21 plots each measuring 5 m × 4 m. Seeds were sown in rows 20 cm apart at a seed rate of 80 kg ha⁻¹ on 18 June 2023. Pre-emergence herbicides were applied at 3 DAS with a knapsack sprayer delivering 500 L ha⁻¹ spray volume, and post-emergence herbicides at 25 DAS.

Methods

Weed density was recorded at 30, 60, and 90 DAS using a 0.25 m² quadrat placed at two random spots per plot; counts were converted to per square metre values. Weed dry weight was determined after oven-drying at 70 °C for 72 h. Weed control efficiency (WCE) was calculated as [(weed dry weight in weedy check - weed dry weight in treatment) / weed dry weight in weedy check] × 100 ^[13]. Crop growth parameters—plant height, tiller count, and leaf area index—were measured at 60 DAS. Grain yield was recorded from a net plot area of 12 m² after harvesting, threshing, and adjusting moisture to 14%. Data were analysed using

ANOVA in R (v 4.3.1), and treatment means separated by Tukey's HSD at $p < 0.05$.

Results

Weed flora in the experimental field comprised 14 species, dominated by *Echinochloa colona* (32% of total density), *Cyperus iria* (21%), *Ludwigia parviflora* (14%), and *Digitaria sanguinalis* (11%). Across all observation dates, herbicide-treated plots recorded markedly lower weed populations than the weedy check.

Table 1: Effect of herbicide treatments on weed density (no. m⁻²) at different growth stages

Treatment	30 DAS	60 DAS	90 DAS	WCE (%)
Pendi. + Bispyribac	38.2	24.6	19.3	71.8
Pendi. + Fenoxaprop	41.7	31.8	26.1	63.5
Oxyfl. + Bispyribac	39.4	28.4	22.7	67.4
Pendi. alone	44.1	42.7	38.9	51.1
Weedy check	86.3	87.3	79.6	—
Weed free	0.0	0.0	0.0	100
CD (p=0.05)	6.8	5.4	4.9	7.1

Pendi. = Pendimethalin; Oxyfl. = Oxyfluorfen; DAS = days after sowing; WCE = weed control efficiency at 60 DAS.

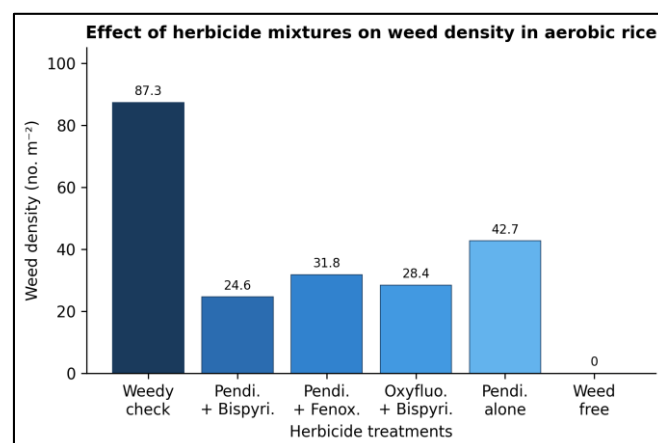


Fig 1: Effect of herbicide mixtures on weed density (no. m⁻²) at 60 DAS in aerobic rice

Table 2: Crop growth and yield parameters under different herbicide treatments

Treatment	Plant ht. (cm)	Tillers m ⁻²	LAI	Yield (t/ha)	HI
Pendi.+Bispy.	78.4	312	4.21	4.38	0.41
Pendi.+Fenox.	74.9	287	3.87	3.92	0.39
Oxyfl.+Bispy.	76.1	298	4.03	4.15	0.40
Pendi. alone	71.3	254	3.46	3.28	0.37
Weedy check	62.7	198	2.71	2.34	0.33
Weed free	80.2	324	4.38	4.51	0.42
CD (p=0.05)	4.3	21.6	0.32	0.29	NS

LAI = leaf area index at 60 DAS; HI = harvest index; NS = non-significant.

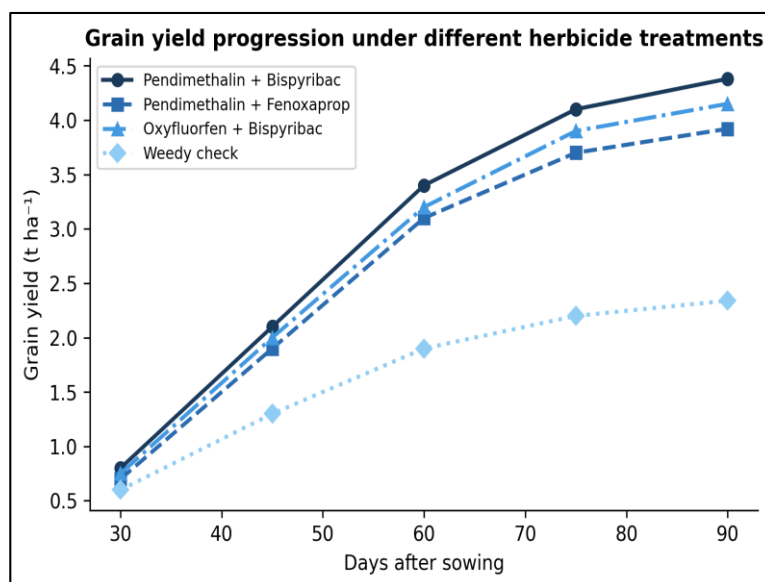


Fig 2: Grain yield progression (t ha^{-1}) under different herbicide treatments across crop growth stages

Table 3: Economics of weed management in direct seeded aerobic rice

Treatment	Gross return (₱/ha)	Cost of weeding (₱/ha)	Net return (₱/ha)	B:C ratio
Pendi.+Bispy.	87,600	4,350	48,250	2.23
Pendi.+Fenox.	78,400	4,100	39,300	2.01
Oxyfl.+Bispy.	83,000	4,500	43,500	2.10
Pendi. alone	65,600	2,800	27,800	1.74
Weedy check	46,800	0	11,800	1.34
Weed free	90,200	14,800	40,400	1.81

B:C = benefit-cost ratio; returns based on paddy price of ₱20,000 t^{-1} .

Comprehensive Interpretation

All herbicide mixtures suppressed weed density below 45 no. m^{-2} by 60 DAS, compared with 87.3 no. m^{-2} in the weedy check. The sequential application of pendimethalin followed by bispyribac-sodium stood out, cutting weed density by 71.8% and raising grain yield to 4.38 t ha^{-1} —a figure statistically comparable to the weed-free control (4.51 t ha^{-1}). Pendimethalin alone, while reducing early-season weeds, failed to control late-emerging grasses, and its yield (3.28 t ha^{-1}) remained markedly below that of the mixtures. The economic analysis confirmed that the pendimethalin + bispyribac combination returned the highest B:C ratio (2.23), outperforming even the weed-free treatment (1.81) because hand weeding costs were three times higher.

Discussion

The dominance of *Echinochloa colona* and *Cyperus iria* in the weed flora matches earlier reports from aerobic rice ecosystems across Southeast Asia, where these species exploit the moist, non-flooded soil surface to germinate rapidly after sowing [2]. Pendimethalin applied at 3 DAS effectively arrested the first weed flush by inhibiting root and shoot elongation of germinating seedlings, but its residual activity tapered off by 20-25 DAS, allowing a second flush of grasses—a pattern also observed by Rao *et al.* [7] in lowland rice areas.

And this is precisely where the post-emergence partner made the difference. Bispyribac-sodium, applied at 25 DAS, targeted the surviving and newly emerged grasses through ALS inhibition, extending the weed-free window to 45-50

DAS. A similar two-phase suppression was reported by Singh *et al.* [8] in the Central Luzon lowlands, though their trial used higher bispyribac rates (30 g a.i. ha^{-1}). That a lower rate (25 g a.i. ha^{-1}) proved adequate in the present trial may reflect the laterite soil's lower organic matter content, which reduces herbicide adsorption and increases bioavailability [14].

Fenoxaprop-p-ethyl, while effective against grasses, showed no activity on sedges or broadleaved weeds, leaving *Cyperus iria* and *Ludwigia parviflora* uncontrolled—a gap that explains the 12% lower WCE relative to the bispyribac combination. This selectivity limitation is consistent with findings of Kumar and Gill [5], who recommended adding a broadleaf-active partner wherever sedge pressure is high.

From a practical standpoint, the superior B:C ratio of the pendimethalin + bispyribac mixture over the weed-free control holds particular relevance for smallholders, because labour for hand weeding is both scarce and expensive during the wet-season peak.

Conclusion

This research set out to identify an effective, economical herbicide mixture for weed management in direct seeded aerobic rice under the agro-climatic conditions of the Visayas region of the Philippines. Among the five treatments tested, the sequential application of pendimethalin (1000 g a.i. ha^{-1}) at 3 DAS followed by bispyribac-sodium (25 g a.i. ha^{-1}) at 25 DAS achieved the highest weed control efficiency (71.8%), produced a grain yield (4.38 t ha^{-1}) statistically at par with the weed-free control, and returned the best B:C ratio (2.23) among all treatments. Oxyfluorfen followed by bispyribac-sodium was the next best option, while pendimethalin alone proved inadequate against late-season grasses. These findings point to a clear, actionable recommendation for farmers in the Visayas highlands transitional zone: a two-step herbicide programme anchored on pendimethalin and bispyribac-sodium can replace costly manual weeding without sacrificing yield. Future work should test this mixture over multiple seasons, evaluate its effect on soil microbial health, and determine the optimum spray volume under varying rainfall conditions in the region.

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