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Resistance of Barnyardgrass (*Echinochloa crus-galli*) to Butachlor in direct-seeded rice in Hue city, Vietnam

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ABSTRACT

Barnyardgrass is a significant threat to rice production, causing substantial yield losses and evolving resistance to multiple herbicides. However, the occurrence of Butachlor resistance in Central Vietnam remains poorly understood, highlighting the need for its assessment in Hue City rice fields. This study evaluated the resistance of Barnyardgrass populations to Butachlor in Kim Tra ward, Hue City (16°302 353 N, 107°312 563 E; elevation: 0 m) during the 2024–2025, where Barnyardgrass (*Echinochloa crus-galli*) had been consistently observed surviving after herbicide application. A single-factor experiment was conducted with five treatments: a control (no herbicide application), and Butachlor applications at 0.5x, 1.0x (recommended dose of 0.3 kg a.i./ha), 1.5x, and 2.0x the recommended dose. Results indicated that Barnyardgrass in this region has begun to develop resistance to Butachlor. At the recommended dose, herbicide efficacy was only 38.9% at 14 days after treatment (DAT). While the 2.0x dose achieved 100% efficacy, Barnyardgrass survived and competed with rice at the recommended dose, leading to a 2.1% yield loss compared to weed-free conditions. In contrast, untreated plots suffered a 22.2% yield reduction. These findings suggest an urgent need for revised weed management strategies in Central Vietnam to mitigate the spread of herbicide resistance.

Key words: Butachlor, *Echinochloa crus-galli*, herbicide resistance

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the world's most important staple crops, cultivated in about 113 countries on nearly 168 million hectares (FAO, 2024). Rice is central to food security in Southeast Asia and an important export commodity. Vietnam has about 7.4 million hectares of rice, making it essential to national food security (National Statistics Office, 2025).

Rice production is constrained by weeds, insects, diseases, and rodents. Weeds compete for light, water, nutrients, and space and may harbour other pests. Weed competition can reduce yield by 30–60% in direct-seeded rice in Asia and by about 46% in Vietnam (Duong and Ho, 2010; Matloob *et al.,* 2015; Thi *et al.,* 2026).

Barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.) is a widespread and troublesome rice weed worldwide (Baltazar, 2017; Ulguim *et al.,* 2020; Wu *et al.,* 2022), causing yield losses of 27–79 % (Zhang *et al.,* 2017). Herbicides are widely used in Vietnam, but repeated use favours resistant populations (Nguyen *et al*., 2017; Thi *et al.,* 2026).

Herbicide resistance is the inherited ability of a weed population to survive and reproduce after a normally effective dose. Since *Commelina diffusa* was reported as the first resistant weed in the United States in 1957, 514 resistance cases involving 262 weed species have been documented in 71 countries (Heap, 2025). *E. crus-galli* has evolved resistance to pretilachlor, Butachlor, propanil, penoxsulam, and several ALS- and ACCase-inhibiting herbicides (Qing-ya *et al.,* 2004; Juliano *et al.,* 2010; Won *et al.,* 2014; Chen *et al.,* 2016; Heap, 2025).

Hu *et al.* (2025) surveyed 510 *Echinochloa* populations in Jiangsu, China, during 2018–2022. Penoxsulam resistance increased nearly ninefold, quinclorac

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resistance remained above 40% for four years, and resistance to cyhalofop-butyl and bispyribac-sodium also increased. Pretilachlor and metamifop remained comparatively effective, while cross- and multiple-resistance increased.

In Vietnam, herbicide-resistance research remains limited (Le, 2017; Le *et al.,* 2017; Le *et al.,* 2018). Cyhalofop-butyl-resistant *E. crus-galli* was first reported in An Giang, and 78 Mekong Delta populations were later shown to resist bispyribac-sodium, penoxsulam, and quinclorac. Barnyardgrass regrowth has recently been observed in Central Vietnam, but Butachlor resistance has not been systematically investigated.

Therefore, this study aimed to assess the response of *E. crus-galli* in rice fields of Hue City to Butachlor and provide baseline information for resistance management in Central Vietnam.

MATERIALS AND METHODS

Experimental Materials

The experiment was conducted in Kim Trà Ward, Hue City (16°302 353 N, 107°312 563 E; elevation 0 m), where Barnyardgrass had repeatedly survived herbicide applications. Echo 60EC containing Butachlor was evaluated during the 2024–2025 winter–spring rice season.

Experimental Design and Data Collection

A single-factor field experiment included T1, untreated control; T2, Butachlor at 0.5×; T3, recommended rate (0.3 kg a.i./ha); T4, 1.5×; and T5, 2.0× the recommended rate. The RCBD had three replications. Plots were 4 × 3 m (12 m^2), separated by 0.5 m. Herbicide was applied one day after sowing at 320 L/ha. Water was maintained at 4–7 cm from five to 30 days after application. NPK (16-16-8) was applied at 600 kg/ha in three equal applications at 15, 30, and 45 days after sowing.

Weed density was assessed with a 40 × 50 cm quadrat at five diagonal points per plot at 14, 21, and 28 DAA and at maximum tillering, panicle initiation, and heading. Weeds were identified, counted, weighed, and oven-dried at 70°C to constant weight. Herbicide efficacy was calculated using the method described by Abbott (1925). Rice height and tiller number were recorded from 10 plants per plot. Grain yield was measured from 4 m^2 at maturity at 14% moisture; five 200-grain samples per treatment were used for 1000-grain weight.

Statistical Analysis

Data on weed density, herbicide efficacy, rice height, tiller number, weed biomass, yield components, and grain yield were analysed by one-way ANOVA. Treatment means were compared using Tukey's HSD test at P d" 0.05 in Microsoft Excel 2016 and SPSS v.16.

RESULTS AND DISCUSSION

Evaluation of Barnyardgrass Response to Butachlor Under Field Conditions

Herbicidal Efficacy of Butachlor at Different Rice Growth Stages

Table 1 shows incomplete Barnyardgrass control at the recommended rate. At 14 DAA, density was 8.7 plants/m^2 in T1 and 0.7 in T5. Efficacy ranged from 30.8% in T2 to 91.9% in T5; T3 provided 38.9% control. Other weeds showed 77.8% control at T3 and 100% at T4 and T5.

At 14 DAA, Barnyardgrass density was 8.7 plants/m^2 in T1 and 0.7 in T5. Efficacy ranged from 30.8% in T2 to 91.9% in T5; T3 provided only 38.9% control. Other weeds showed 77.8% control at T3 and 100% at T4 and T5.

At panicle initiation, Barnyardgrass density was 27.3 plants/m^2 in T1 and 0 in T5. T3 provided 87.9% control, whereas all treated plots had 100% control of other weed species.

At heading, Barnyardgrass density was 30.0 plants/m^2 in T1 and 0 in T5. T3 achieved 69.0% control, while other weeds were absent from treated plots. Weed density then remained stable to maturity.

The Kim Trà population survived the recommended and 1.5 × rates despite correct application. Under Juliano *et al.* (2010), these findings provide preliminary evidence of reduced sensitivity or developing resistance. Confirmation requires dose-response tests across locations and seasons.

Table 1. Efficacy of Butachlor against weed populations in direct-seeded rice fields in Kim Tra, Hue City

Treatment[1]	Before application		14 days after application		21 days after application		28 days after application		Tillering		Panicle		Heading		15 days after heading	
	WD (plant/m^2)	HE (%)	WD[2] (plant/m^2)	HE[3] (%)	WD (plant/m^2)	HE (%)	WD (plant/m^2)	HE (%)	WD (plant/m^2)	HE (%)	WD (plant/m^2)	HE (%)	WD (plant/m^2)	HE (%)	WD (plant/m^2)	HE (%)
Weed (Ec)																
T1	0	-	8.7^{a}	-	22.7^{a}	-	36.0^{a}	-	66.7^{a}	-	27.3^{a}	-	30.0^{a}	-	30.0^{a}	-
T2	0	-	6.0^{ab}	30.8	11.3^{ab}	50.2	26.0^{ab}	27.8	29.3^{ab}	56.1	20.7^{b}	24.2	10.0^{b}	66.7	10.0^{b}	66.7
T3	0	-	5.3^{ab}	38.9	7.3^{ab}	67.8	10.7^{ab}	70.3	9.3^{b}	86.1	3.3^{c}	87.9	9.3^{b}	69.0	9.3^{b}	69.0
T4	0	-	2.0^{b}	76.9	0.7^{b}	96.9	4.0^{b}	88.9	3.3^{b}	95.1	0.7^{c}	97.4	0.0^{b}	100.0	0.0^{b}	100.0
T5	0	-	0.7^{b}	91.9	0.0^{c}	100.0	0.0^{b}	100.0	0.0^{b}	100.0	0.0^{c}	100.0	0.0^{b}	100.0	0.0^{b}	100.0
Total weeds																
T1	0	-	6.0^{a}	-	146.0^{a}	-	86.7^{a}	-	261.3^{a}	-	19.3^{a}	-	13.7^{a}	-	13.7^{a}	-
T2	0	-	2.0^{a}	66.7	54.7^{ab}	62.7	30.0^{ab}	65.4	90.0^{ab}	65.5	0.0^{b}	100.0	0.0^{b}	100.0	0.0^{b}	100.0
T3	0	-	1.3^{a}	77.8	30.0^{ab}	79.5	26.0^{ab}	70.0	9.3^{ab}	96.4	0.0^{b}	100.0	0.0^{b}	100.0	0.0^{b}	100.0
T4	0	-	0.0^{a}	100.0	27.3^{ab}	81.4	2.7^{b}	96.9	0.7^{b}	99.7	0.0^{b}	100.0	0.0^{b}	100.0	0.0^{b}	100.0
T5	0	-	0.0^{a}	100.0	1.3^{b}	99.6	0.0^{b}	100.0	0.0^{b}	100.0	0.0^{b}	100.0	0.0^{b}	100.0	0.0^{b}	100.0

[1]T1. untreated control (no herbicide application); T2. 0.5× the recommended rate; T3. recommended rate (0.3 kg a.i./ha); T4. 1.5× the recommended rate; T5. 2× the recommended rate.
[2]WD: Weed density; [3]HE: Herbicide efficiency; Treatment means were compared using Tukey's Multiple Comparison Test. Means followed by different letters in the same column differ significantly ($P \leq 0.05$).

Butachlor Response of *Echinochloa crus-galli* Based on Weed Biomass

Table 2 shows rate-dependent reduction of Barnyardgrass biomass. At maximum tillering, fresh biomass was 290.0 g/m² in T1, 60.0 in T3, and 0 in T5; dry biomass followed the same pattern. Other weed biomass was low, and differences were generally not significant. After heading, weed density and biomass remained relatively stable until maturity.

Effects of Weed Infestation on Rice Growth and Grain Yield

Effects of Weed Infestation on Plant Height

Table 3 shows that rice height increased until heading and then stabilised. No significant differences occurred at tillering. At panicle initiation, heights were 76.1 cm in T5 and 72.7 cm in T1; at heading, 91.7 and 88.0 cm, respectively, with the control significantly shorter.

Overall, uncontrolled weeds reduced rice height from panicle initiation onward, indicating increasing competition for environmental resources as weed density increased.

Effects of Weed Infestation on Tillering

Table 4 shows more tillers in treated plots. At maximum tillering, T5 had 1,102.0 and T1 925.3 tillers/m², without significant difference. At panicle initiation, T5 had 1,238.7 and T1 985.3 tillers/m², with a significant difference. At heading, T5 had 837.3 and T1 642.7 tillers/m²; T1 differed from T4 and T5.

Table 2. Weed biomass in direct-seeded rice fields in Kim Tra, Hue City following herbicide application

Treatment[1]	Weed biomass (g/m²)[2]							
	Tillering stage		Panicle		Heading		Ripening	
	Fresh[2]	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Weed ((Ec)								
T1	290.0[a]	51.4[a]	470.0[a]	149.8[a]	333.3[a]	78.6[a]	333.3[a]	78.6[a]
T2	153.3[ab]	23.3[b]	183.3[ab]	43.8[b]	126.0[b]	34.5[ab]	126.0[b]	34.5[ab]
T3	60.0[b]	5.8[b]	66.7[b]	14.6[b]	76.7[b]	14.3[b]	76.7[b]	14.3[b]
T4	46.7[b]	1.1[b]	53.3[b]	18.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
T5	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Total weeds								
T1	46.0[a]	4.3[a]	13.3[a]	1.6[a]	40.0[a]	11.1[a]	40.0[a]	11.1[a]
T2	14.0[ab]	1.1[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	3.3[a]	0.0[a]
T3	0.3[b]	0.0[a]	0.0[a]	0.0[a]	3.3[a]	0.3[a]	0.0[a]	0.3[a]
T4	0.0[b]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
T5	0.0[b]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]

[1]T1. Untreated control (no herbicide application); T2. 0.5 × Recommended rate; T3. Recommended rate (0.3 kg a.i./ha); T4. 1.5 × Recommended rate; T5. 2 × Recommended rate.
[2]Treatment means were compared using Tukey's Multiple Comparison Test. Means followed by different letters in the same column differ significantly (P≤0.05).

Table 3. Rice plant height at different growth stages

Treatment[1]	Plant height (cm) at various growth stages[2]			
	Tillering	Panicle	Heading	Ripening
T1	46.8[a]±0.3	72.7[a]±0.8	88.0[a]±0.7	88.0[a]±0.7
T2	47.6[a]±0.4	75.6[b]±0.7	90.6[b]±0.6	90.6[b]±0.6
T3	47.8[a]±0.3	75.5[b]±0.4	90.6[b]±0.5	90.6[b]±0.5
T4	47.6[a]±0.3	75.9[b]±0.6	91.2[b]±0.7	91.2[b]±0.7
T5	47.8[a]±0.2	76.1[b]±0.4	91.7[b]±0.6	91.7[b]±0.6

[1]T1. Ucontrol (no herbicide application); T2. 0.5 × Recommended rate; T3. Recommended rate (0.3 kg a.i./ha); T4. 1.5 × Recommended rate; T5. 2 × Recommended rate.
[2]Numbers following "±" are the standard error of the mean. Treatment means were compared using Tukey's Multiple Comparison Test. Means followed by different letters in the same column differ significantly (P≤0.05).

Overall, weed infestation suppressed rice tillering from panicle initiation onward. Effective weed management reduced competition for light, water, and nutrients and maintained a greater number of productive tillers.

Effects of Weed Infestation on Yield Components and Grain Yield

Table 5 shows panicle density of 642.7/m² in T1 and 837.3/m² in T5, with significant differences between T1 and T4-T5. Filled grains per panicle were 101.7 in T1 and 116.5 in T5. 1000-grain weight (18.1-18.7 g) did not differ significantly.

Theoretical yield ranged from 11.82 t/ha in T1 to 18.29 t/ha in T5, with significant differences between T1 and T3–T5. Actual yield was 6.42 t/ha in T1 and 8.42 t/ha in T5; all treated plots yielded significantly more than T1.

Level of Butachlor Resistance in Barnyardgrass

Table 6 shows grain yield of 6.42 t/ha in T1 versus 7.83-8.42 t/ha in T2-T5. Yield reduction was 22.2% in T1 and 2.1% at the recommended rate; no measurable reduction occurred at 1.5× or 2.0×. The economic effect was limited.

Table 4. Rice tillering capacity at different growth stages

Treatment[1]	**Number of tillers/m²			
	Tillering	Panicle	Heading	Ripening
T1	925.3^{a}±54.4	985.3^{a}±66.4	642.7^{a}±29.4	642.7^{a}±29.4
T2	1067.3^{a}±45.9	1190.7^{ab}±80.7	786.0^{ab}±34.9	786.0^{ab}±34.9
T3	1095.3^{a}±31.3	1156.7^{ab}±45.9	791.3^{ab}±31.7	791.3^{ab}±31.7
T4	1032.7^{a}±57.3	1092.7^{ab}±59.1	826.0^{b}±50.3	826.0^{b}±50.3
T5	1102.0^{a}±6.4	1238.7^{b}±25.4	837.3^{b}±31.4	837.3^{b}±31.4

*T1. Untreated control (no herbicide application); T2. 0.5 × Recommended rate; T3. Recommended rate (0.3 kg a.i./ha); T4. 1.5 × Recommended rate; T5. 2 × Recommended rate.
**Numbers following "±" are the standard error of the mean. Treatment means were compared using Tukey's Multiple Comparison Test. Means followed by different letters in the same column differ significantly (P≤0.05).

Table 5. Effects of weeds on yield components and grain yield of rice

*Treatment	**Panicle/m² (panicle)	Filled grains/ panicle (g)	1000-grain weight (g)	Theoretical yield (t/ha)	Actual grain yield (t/ha)
T1	642.7^{a}±29.4	101.7^{a}±1.0	18.1^{a}±0.1	11.82^{a}±5.3	6.42^{a}±3.0
T2	786.0^{ab}±34.9	106.4^{b}±0.9	18.1^{a}±0.2	15.13^{ab}±8.3	7.83^{b}±1.7
T3	791.3^{ab}±31.7	110.7^{b}±1.3	18.7^{a}±0.2	16.35^{b}±5.3	8.08^{b}±3.6
T4	826.0^{b}±50.3	116.2^{c}±1.1	18.6^{a}±0.2	17.87^{b}±13.8	8.25^{b}±1.4
T5	837.3^{b}±31.4	116.5^{c}±1.2	18.7^{a}±0.2	18.29^{b}±5.8	8.42^{b}±2.0

*T1. Untreated control (no herbicide application); T2. 0.5 × Recommended rate; T3. Recommended rate (0.3 kg a.i./ha); T4. 1.5 × Recommended rate; T5. 2 × Recommended rate.
**Numbers following "±" are the standard error of the mean. Treatment means were compared using Tukey's Multiple Comparison Test. Means followed by different letters in the same column differ significantly (P≤0.05).

Table 6. Effects of Butachlor herbicide on weed density and rice yield

Parameter	**Untreated control	0.5 × Recommended rate	Recommended rate	1.5 × Recommended rate	2 × Recommended rate
Echinochloa crus-galli density (plant/m²)	30.0^{a}±2.9	10.0^{b}±3.5	9.3^{b}±4.2	0.0^{b}	0.0^{b}
Other weed density (plant/m²)	13.7^{a}±13.7	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
Yield (t/ha)	6.42^{a}±3.0	7.83^{b}±1.7	8.08^{b}±3.6	8.25^{b}±1.4	8.42^{b}±2.0
Yield reduction (%)*	22.2	5.1	2.1	-	-

*Yield reduction (%) = [(Yield in weed-free plots " Yield in weedy plots) / Yield in weed-free plots] × 100 (Misra and Misra, 1997).
**Numbers following "±" are the standard error of the mean. Treatment means were compared using Tukey's Multiple Comparison Test. Means followed by different letters in the same column differ significantly (P≤0.05).

Butachlor resistance in *E. crus-galli* has been reported in Asian rice systems. Bingqlu and Shaoxiang (1993) reported resistant populations in China after 8-12 years of continuous use; Huang and Gressel (1997) documented survival at the recommended rate. Juliano *et al.* (2010) found multiple resistance in 17 of 18 Philippine populations, including Butachlor + propanil. Baltazar (2017) linked resistance to repeated use in rice monoculture. Umurzokov *et al.* (2023) found most Korean populations susceptible to Butachlor and Pretilachlor; Riechers *et al.* (2024) reported cross-resistance involving Butachlor in China. Guo *et al.* (2026) found low-to-moderate resistance in three of 20 Guangdong populations. The present evidence suggests reduced sensitivity in Kim Tra ward; confirmation requires dose–response assays and resistance-index determination.

CONCLUSION

The *E. crus-galli* population in Kim Trà Ward, Hue City, showed reduced sensitivity to Butachlor. At the recommended rate, efficacy was 38.9% at 14 DAA, and Barnyardgrass survived and regenerated. Untreated plots suffered a 22.2% yield reduction, whereas yield loss at the recommended rate was 2.1%. These findings provide preliminary field evidence of reduced sensitivity. Dose–response bioassays, resistance-index determination, and physiological or molecular studies are needed for confirmation.

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