International Journal of Life Science and Agriculture Research

ISSN (Print): 2833-2091, ISSN (Online): 2833-2105

Volume 04 Issue 12 December 2025

DOI: https://doi.org/10.55677/ijlsar/V04I12Y2025-08

Impact Factor: 7.88 , Page No : 782-787

Weed Community Shift and Crop Tolerance in No-Tillage Rice under Sequential Application of Glyphosate and Cyhalofop-butyl plus Ethoxysulfuron

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ABSTRACT

The reliance on chemical weed control in No-Tillage (NT) rice systems often leads to ecological changes in weed community composition and raises concerns regarding crop safety. This research aimed to evaluate the dynamics of weed community shift (SDR) and assess crop tolerance following the sequential application of glyphosate (pre-plant) and a mixture of cyhalofop-butyl + ethoxysulfuron (post-emergence). The experiment was conducted from May to October 2025 at the Experimental Farm of Universitas Padjadjaran, using a Split-Plot Design with three replications. The results indicated a significant weed composition shift from a community dominated by broadleaves (Limnocharis flava and Salvinia molesta) before application to a grass-dominated community (Echinochloa crus-galli and Leptochloa chinensis) at 3 weeks after application (WAA). Regarding crop tolerance, transient phytotoxicity symptoms in the form of leaf chlorosis were observed at 1 WAA, particularly in the highest dose treatment (1.75 L/ha). However, the rice plants demonstrated a rapid physiological recovery mechanism, with symptoms disappearing completely by 3 WAA. This recovery was confirmed by the vegetative growth response, where the number of vegetative tillers showed no significant inhibition compared to the manual weeding control during the active tillering phase. These findings suggest that sequential application of these herbicides effectively manages the weed spectrum shift and remains agronomically safe due to the crop's high resilience.

Published Online: December 29, 2025

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KEYWORDS: Cyhalofop-butyl, Ecological Shift, Ethoxysulfuron, Phytotoxicity, Weeds.

INTRODUCTION

No-tillage rice production is increasingly considered a practical pathway to improve field operations efficiency while maintaining yield stability. Weed pressure remains a primary biological constraint in rice because early-season interference can suppress crop growth and compromise yield components under a wide range of establishment methods (Shekhawat *et al*., 2020). Weed management becomes more complex in reduced-tillage systems because fewer soil disturbances can favor repeated recruitment from the surface seedbank and enable persistent species to dominate (Sims *et al*., 2018). Conservation-oriented rice systems often rely on well-timed herbicide programs to secure a sufficiently long weed-free period when labor is limited and mechanical options are constrained (Zahan *et al*., 2021). Ecologically informed weed management is therefore needed to sustain productivity while limiting the long-term risks associated with simplified control tactics (MacLaren *et al*., 2020).

No-tillage systems can unintentionally reshape weed communities through consistent selection pressures across seasons. Repeated use of similar herbicide modes of action can accelerate shifts in dominant species and increase the likelihood of hard-to-control populations emerging in the same production landscape (Beckie & Harker, 2017). Herbicide resistance has become a central concern in modern weed management because it undermines control reliability and raises costs for growers (Beckie, 2020). Grass weeds in rice, including Echinochloa spp., have been reported with increasing resistance issues in intensively managed rice areas, which can reduce the effectiveness of post-emergence options (Rouse *et al*., 2018). Weed community change is also shaped by how weed control interacts with crop establishment and water management, reinforcing the need to evaluate species composition alongside biomass reduction (Sims *et al*., 2018).

Sequential herbicide programs are commonly adopted to synchronize control with staggered weed emergence patterns in no-tillage rice. Global trends show that glyphosate use expanded markedly as it became a cornerstone for pre-plant vegetation control in reduced-tillage systems (Benbrook, 2016). Environmental persistence and off-field movement of glyphosate can vary across sites, so its use benefits from evidence-based stewardship that considers local soil and climatic conditions (Kanissery *et al*., 2019). Post-emergence grass control in rice can be strengthened by ACCase-inhibiting herbicides such as cyhalofop-butyl, which has been reported as effective and selective for rice in field applications targeting grass weeds (Umiyati *et al*., 2021). Broader-spectrum post-emergence control can be supported by mixtures containing ethoxysulfuron to improve suppression of diverse weed flora in rice production settings (Yadav *et al*., 2019).

MATERIALS AND METHODS

Place and Time of research

The study was conducted at the rice fields located in Jelekong Village, Ciparay District, Bandung Regency, West Java. The research activities were carried out from May to October 2025.

Tools and materials

The materials used were rice seeds of Cakrabuana Agritan variety, glyphosate herbicide (pre-plant), and a premix herbicide containing cyhalofop-butyl and ethoxysulfuron (post-emergence). The tools employed included a semi-automatic knapsack sprayer, quadrat frame (0.5 m x 0.5 m) for weed sampling, analytical scale, drying oven, and stationery.

Research design

This study employed a factorial experimental method arranged in a Randomized Block Design (RBD) with a Split-Plot pattern, consisting of two factors. The main plot was the dose of glyphosate, comprising: G0 = 0 L/ha; G1 = 2 L/ha; G2 = 3 L/ha; and G3 = 4 L/ha. The sub-plot was the dose of herbicide mixture, consisting of: H0 = 0 L/ha; H1 = 0.75 L/ha; H2 = 1.00 L/ha; H3 = 1.25 L/ha; H4 = 1.50 L/ha; and H5 = 1.75 L/ha. This resulted in 24 treatment combinations, replicated 3 times. Data were analyzed using Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at the 5% level.

RESULTS

Weed Community Composition Shift

The analysis of the Summed Dominance Ratio (SDR) showed that sequential herbicide application significantly altered the weed vegetation structure compared to the initial condition. The dominance of broadleaf weeds at the pre-plant stage shifted towards grass weeds at 3 Weeks After Application (WAA). The dynamics of dominant weed species composition are presented in Table 1.

Table 1. Weed composition shift based on Summed Dominance Ratio (SDR) before and after herbicide application

No.	Weed Species	Group of Weeds	SDR (%) Before Application	SDR % 3 WAA
1	*Limnocharis flava*	Broadleaves	19,65	7,75
2	*Salvinia molesta*	Broadleaves	16,27	6,24
3	*Cyperus difformis*	Sedges	10,03	8,86
4	*Cyperus iria*	Sedges	7,82	7,29
5	*Fimbristylis littoralis*	Sedges	6,99	6,78
6	*Monochoria vaginalis*	Broadleaves	5,54	9,99
7	*Sphenoclea zeylanica*	Broadleaves	5,37	8,62
8	*Echinochloa crus-galli*	Grasses	5,16	9,17
9	*Leptochloa chinensis*	Grasses	4,94	8,96
10	*Ludwigia hyssopifolia*	Broadleaves	4,65	9,55
11	*Marsilea crenata*	Broadleaves	3,69	3,95

Note: WAA: Week After Application

Crop Injury and Physiological Recovery

The results of visual scoring based on the Pesticide Commission Scale (1984) indicated that the application of the herbicide mixture caused transient phytotoxicity symptoms in the form of leaf chlorosis at 1 WAA. The highest injury percentage was observed in the combination of glyphosate and the highest dose of herbicide mixture (1.75 L/ha). However, the observations at 2 WAA showed a significant reduction in injury symptoms, and by 3 WAA, the plants had fully recovered (0% injury). The percentage of crop injury is presented in Table 2.

Table 2. Percentage of rice crop injury observed based on Pesticide Commission Scale (1984) at 1, 2, and 3 WAA

Glyphosate (L/ha)	Cyhalofop-butyl + Ethoxysulfuron (L/ha)	1 WAA		2 WAA		3 WAA	
		Scale	%	Scale	%	Scale	%
0 (G0)	0 (H0)	0	0	0	0	0	0
	0.75 (H1)	0	0	0	0	0	0
	1.00 (H2)	0	0	0	0	0	0
	1.25 (H3)	0	5	0	0	0	0
	1.50 (H4)	1	10	0	5	0	0
	1.75 (H5)	1	15	0	5	0	0
2 (G1)	0 (H0)	0	0	0	0	0	0
	0.75 (H1)	0	0	0	0	0	0
	1.00 (H2)	0	0	0	0	0	0
	1.25 (H3)	0	5	0	0	0	0
	1.50 (H4)	0	5	0	0	0	0
	1.75 (H5)	1	10	0	0	0	0
3 (G2)	0 (H0)	0	0	0	0	0	0
	0.75 (H1)	0	0	0	0	0	0
	1.00 (H2)	0	0	0	0	0	0
	1.25 (H3)	0	0	0	0	0	0
	1.50 (H4)	1	10	0	5	0	0
	1.75 (H5)	1	20	1	5	0	0
4 (G3)	0 (H0)	0	0	0	0	0	0
	0.75 (H1)	0	0	0	0	0	0
	1.00 (H2)	0	0	0	0	0	0
	1.25 (H3)	0	5	0	0	0	0
	1.50 (H4)	1	10	0	5	0	0
	1.75 (H5)	1	15	0	5	0	0

Note: WAA: Week After Application

Vegetative Tiller Number

The analysis of variance showed that there was a significant interaction between glyphosate doses and herbicide mixture doses on the number of vegetative tillers at 56 day after plant (DAP). The data presented in Table 3 indicates that the integration of pre-plant and post-emergence herbicides positively influenced the vegetative proliferation of rice. A consistent trend was observed where increasing the doses of both herbicides resulted in a significantly higher number of tillers. Vertically, at the same level of herbicide mixture (e.g., H5), the highest glyphosate dose (G3) produced the maximum number of tillers (26.00), which was significantly different from the lower doses. Horizontally, increasing the mixture dose within the same glyphosate level also significantly boosted tiller numbers. This suggests that the effective weed suppression provided by the highest treatment combination (G3H5) created a conducive environment for tillering, compensating for the transient injury observed at the earlier stage.

Table 3. Interaction effect of glyphosate and herbicide mixture doses on the number of vegetative tillers at 56 DAP

Glyphosate Dose (L/ha)	Herbicide Mixture Dose (L/ha)					
	H0	H1	H2	H3	H4	H5
G0	9,67 ± 1,43 a A	14,00 ± 0,00 a B	14,33 ± 1,43 a BC	15,00 ± 0,00 a C	16,00 ± 0,00 a D	17,67 ± 1,43 a E
G1	13,67 ± 1,43 b A	16,67 ± 1,43 b B	17,00 ± 0,00 b B	18,33 ± 1,43 b C	19,33 ± 1,43 b D	20,67 ± 1,43 b E
G2	16,33 ± 1,43 c A	19,00 ± 0,00 c B	20,67 ± 1,43 c C	21,00 ± 0,00 c C	22,00 ± 0,00 c D	23,33 ± 1,43 c E
G3	20,00 ± 0,00 d A	23,00 ± 0,00 d B	23,67 ± 1,43 d B	23,67 ± 1,43 d B	25,67 ± 1,43 d C	26,00 ± 0,00 d C

Note: Mean values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 5% level. Lowercase letters are read vertically (comparing glyphosate doses within the same mixture dose). Uppercase letters are read horizontally (comparing mixture doses within the same glyphosate dose). ± indicates Standard Deviation (SD). G (Glyphosate Dose), H (Mixture Dose: Cyhalofop-butyl + Ethoxysulfuron).

DISCUSSION

The significant shift in weed vegetation composition observed in this study highlights how quickly weed communities can reorganize under repeated herbicide selection in no-tillage rice. Weed composition changes after burndown herbicide use have been documented under Indonesian lowland rice no-tillage preparation where dominant species can shift between observation times (Rifa'i *et al*., 2023). The initial dominance of broadleaf weeds can be strongly reduced by a pre-plant glyphosate burndown because glyphosate is a nonselective systemic herbicide with broad-spectrum activity (Duke, 2020). The subsequent rise of grass weeds is consistent with the field reality that complex weed flora in direct-seeded rice often includes aggressive grasses such as Echinochloa spp. that can escape early control windows (Kumar *et al*., 2018). This pattern reflects weed shifting toward species that match the emergence cohorts and selection filters created by the management program over time (Rifa'i *et al*., 2023).

Implementation of a sequential application strategy is therefore critical to manage successive weed flushes that appear after the initial burndown phase. Sequential herbicide programs in direct-seeded rice have been shown to improve suppression of complex weed flora compared with simpler options by extending control across crop growth stages (Kumar *et al*., 2018). Reliance on a single herbicide target can be risky because repeated selection can favor survivors and shift the effective spectrum of control in the field (Duke, 2020). ACCase-inhibiting graminicides such as cyhalofop-butyl are designed to target grass weeds through disruption of acetyl coenzyme-A carboxylase activity in susceptible plants (Nohatto *et al*., 2016). Sulfonylurea components such as ethoxysulfuron complement this approach by inhibiting ALS and broadening activity against non-grass groups that remain after graminicide-focused control (Thyssen *et al*., 2018).

Visual injury symptoms observed as leaf chlorosis can be interpreted as a short-term physiological response when rice encounters a new herbicide mixture under field conditions. Temporary metabolic disturbance is biologically plausible because ALS-inhibiting sulfonylureas disrupt branched-chain amino acid synthesis at the enzyme level and can trigger transient growth and color responses depending on tolerance capacity (Thyssen *et al*., 2018). Oxidative stress processes may also contribute to visible symptoms because herbicide exposure can alter reactive oxygen balance and antioxidant enzyme activity in rice leaves shortly after application (Nohatto *et al*., 2016). ACCase-inhibiting herbicides have been reported to cause relatively low oxidative disruption in rice compared with other herbicide modes of action, which helps explain why injury can be mild and reversible (Nohatto *et al*., 2016). Field observations under Indonesian no-tillage land preparation further support that early herbicide-based control can proceed without lasting growth penalties when weed suppression is effective (Rifa'i *et al*., 2023).

The rapid recovery capability demonstrated by the rice plants suggests that detoxification and physiological compensation mechanisms functioned efficiently under the tested field environment. Crop tolerance to sulfonylurea herbicides can be strongly influenced by cytochrome P450-mediated metabolism that converts active compounds into less toxic forms in plant tissues (Thyssen *et al*., 2018). Effective early weed control under no-tillage can support recovery because the crop is released from resource competition and can reallocate assimilates to resume vegetative development (Rifa'i *et al*., 2023). Weed management programs that control complex flora across grasses, sedges, and broadleaves are also associated with better crop growth continuity in direct-seeded rice systems (Kumar *et al*., 2018). Low oxidative disturbance after ACCase-inhibitor exposure can further support a quick return to normal function because key antioxidant indicators in rice are less perturbed under some graminicide treatments (Nohatto *et al*., 2016).

The robust vegetative growth and high tiller number despite initial injury indicate that eliminating weed competition is more decisive for crop performance than avoiding minor transient phytotoxicity. Uncontrolled weed competition in direct-seeded rice can drive large yield losses, emphasizing the value of maintaining a weed-suppressed environment during sensitive growth phases (Khippal *et al*., 2025). Programs that suppress complex weed flora help protect crop access to light and nutrients, which supports tiller retention and canopy development in direct-seeded systems (Kumar *et al*., 2018). Indonesian field evidence in lowland rice no-tillage preparation shows that effective glyphosate-based weed control can be aligned with normal rice growth and yield expression under practical conditions (Rifa'i *et al*., 2023). Broad-spectrum herbicide dependence should still be managed carefully because repeated reliance on a narrow chemical strategy can increase selection pressure and shift field outcomes over time (Duke, 2020).

CONCLUSIONS

The sequential application of glyphosate followed by a mixture of cyhalofop-butyl and ethoxysulfuron significantly altered the weed community structure from a broadleaf-dominated spectrum to a grass-dominated composition at 3 WAA. Although the herbicide treatment induced transient phytotoxicity symptoms in the form of leaf chlorosis at 1 WAA, particularly at the highest dose combination (G3H5), the Cakrabuana Agritan rice variety demonstrated a rapid physiological recovery capability with total symptom disappearance by 3 WAA. This strong crop tolerance was further confirmed by the vegetative growth response, where the interaction of herbicide doses resulted in the highest number of vegetative tillers, indicating that the effective suppression of weed competition compensated for the temporary abiotic stress. Consequently, this sequential herbicide strategy is confirmed to be agronomically safe and effective for managing weed dynamics in no-tillage rice cultivation systems.

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