

UNIVERSITI TEKNOLOGI MARA

**EVALUATION OF THE NOVEL
HERBICIDE (TVE29) FOR
PENOXSULAM-RESISTANT
Echinochloa crus-galli CONTROL IN
DIRECT-SEEDED RICE**

**NOOR ARIF AIZUDDIN BIN NOOR
RAHIM**

MSc

July 2026

ABSTRACT

Herbicide-resistant *Echinochloa crus-galli* has become a major constraint in Malaysian rice production, particularly in direct-seeded systems that rely heavily on chemical control. Intensive use of the ALS-inhibiting herbicide penoxsulam has accelerated the evolution of resistant populations, resulting in control failures. This study aimed to (i) confirm and determine the penoxsulam resistance level in *Echinochloa crus-galli*, (ii) investigate the role of enhanced metabolic mechanisms in conferring resistance to penoxsulam, and (iii) identify the optimal rate and timing of TVE29, a new herbicide with a novel mode of action, for controlling penoxsulam-resistant (R) biotypes in rice. Freshly matured resistant and susceptible *E. crus-galli* seeds collected from rice fields in Alor Setar, Kedah, were used in a series of glasshouse and field experiments. Herbicide resistance was characterised through screening and dose–response assays, cytochrome P450-mediated metabolic resistance was investigated using malathion inhibition bioassays, and the efficacy and crop safety of TVE29 were evaluated at different application rates and timings under glasshouse and field conditions. Data were analysed using chi-square analysis, log-logistic regression, and analysis of variance (ANOVA). Dose–response experiments showed that the dosages required to cause 50% survival and 50% growth inhibition for the R biotype were 480 to 535-fold higher than those of the susceptible (S) biotype, confirming severe resistance to penoxsulam along with cross-resistance to bispyribac-sodium. In contrast, pretilachlor, quinclorac, and florypyrauxifen-benzyl provided complete control of both biotypes, indicating that resistance is specific to ALS-inhibiting herbicides. To assess non-target-site resistance, malathion was used as a cytochrome P450 inhibitor. Malathion alone had no effect on either biotype. Penoxsulam and bispyribac-sodium completely inhibited the S biotype, but the R biotype maintained high survival (72–88%) and growth (52–71%). However, malathion pre-treatment followed by ALS inhibitors significantly reduced survival and shoot biomass of the R biotype to near zero, demonstrating that resistance is largely mediated by enhanced metabolic detoxification involving cytochrome P450 enzymes. Glasshouse evaluations showed that TVE29 at 100 g a.i. ha⁻¹ was safe for rice across pre-plant, pre-emergence, and early post-emergence applications, whereas higher rates caused early-stage phytotoxicity. TVE29 provided complete control of the R biotype, with improved efficacy under prolonged standing water. Preliminary field evaluations confirmed that pre-plant TVE29 at 100 g a.i. ha⁻¹ achieved 93–100% significantly higher control of major rice weeds including *Monochoria vaginalis*, *Cyperus iria*, and *Fimbristylis miliacea*, and outperformed hand weeding, particularly against the R biotype, while maintaining excellent rice selectivity. This study confirms that enhanced metabolism mediated by cytochrome P450 enzymes is the primary mechanism responsible for ALS-inhibiting herbicide failure in *E. crus-galli* and demonstrates that TVE29 offers an effective, paddy-safe alternative for managing the R biotype.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful,

All praise and gratitude are due to Allah (SWT) for granting me strength, patience, knowledge, and perseverance to successfully complete this study. Without His mercy, guidance and countless blessings, this research would not have been possible. Peace and salutations be upon Prophet Muhammad (SAW), whose teachings continue to inspire the pursuit of knowledge with sincerity and excellence.

I would like to express my deepest and most sincere appreciation to my main supervisor, Professor Dr Chuah Tse Seng, for his invaluable guidance, constructive feedback, scholarly insight, and continuous encouragement throughout the entire research journey. His patience, wisdom, and dedication to academic excellence have greatly contributed to the completion and quality of this study. I am also sincerely grateful to my co-supervisor, Dr. Dilipkumar Masilamany for his professional advice, thoughtful suggestions, and unwavering support, which have further strengthened the scientific rigor of this research.

My heartfelt gratitude is extended to my beloved parents, Noor Rahim bin Ahmad and , who's endless do'a, sacrifices, and unconditional love have been the foundation of my academic journey. May Allah (SWT) grant them abundant rewards and the highest blessings for their patience and unwavering belief in me. I am equally thankful to my entire family; Noor Aidi Akmal, Noor Aina Syuhana, Noor Afiq Hidayat, and Noor Alia Syuhaila for their constant moral support, emotional encouragement and understanding throughout the challenges faced during this study.

I would also like to express my sincere appreciation to my dedicated teammates, Muhammad Izwan Azlan and Kashturi Gobi, for their cooperation, assistance, and commitment throughout this research. My heartfelt gratitude is also extended to my close friends, Abdul Hakim Asmadi, Hidayatul Syazwani Suhaimi, and Rahil Azhar, for their friendship, encouragement, and moral support during my postgraduate journey. Finally, I wish to express my deepest appreciation to Syakirah Mohamed for her unwavering patience, understanding, and continuous encouragement, which have been a constant source of motivation throughout the completion of this study.

May Allah (SWT) bless and reward all individuals who have contributed directly or indirectly to the completion of this study and accept this effort as a deed that brings benefit to the ummah and the field of knowledge.

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR'S DECLARATION	iii
ABSTRACT	iv
ABSTRAK	v
ACKNOWLEDGEMENT	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	xi
LIST OF FIGURES	xiv
LIST OF SYMBOLS	xvi
LIST OF ABBREVIATIONS	xvii
CHAPTER 1 INTRODUCTION	1
1.1 Research Background	1
1.2 Problem Statement	2
1.3 Hypothesis	3
1.4 Research Questions	4
1.5 Research Objectives	4
1.6 Significance of Study	5
1.7 Scope and Limitations of Study	5
CHAPTER 2 LITERATURE REVIEW	7
2.1 Current Status of Rice Industry in Malaysia	7
2.2 Rice Varieties in Malaysia	7
2.2.1 Growth Phase of Paddy	9
2.3 Rice Cultivation in Malaysia	10
2.3.1 Common Weed Species Infesting Rice Fields	12
2.4 <i>Echinochloa crus-galli</i>	13
2.4.1 Botany of <i>E. crus-galli</i>	14

CHAPTER 1

INTRODUCTION

1.1 Research Background

Weeds are among the most serious biotic constraints affecting rice production worldwide and can cause substantial yield losses when control measures are inadequate. The composition of weed flora in rice ecosystems is strongly influenced by cultivation practices; nevertheless, grasses, sedges, and broadleaf weeds consistently dominate most rice fields. In Malaysia, the grassy weed *Echinochloa crus-galli* has emerged as the most problematic species following the widespread adoption of direct-seeded rice (DSR) systems since the 1970s (Khaliq et al., 2012). This species is now officially recognised as a noxious weed due to its aggressive growth and competitive ability (Bajwa et al., 2015).

Compared with transplanted rice (TPR), weed management in DSR systems is inherently more complex. In DSR, rice and weed seedlings emerge simultaneously, creating intense early-season competition for light, nutrients, and space. Under these conditions, *E. crus-galli* is particularly competitive and can rapidly dominate rice fields if not effectively controlled (Rao et al., 2007). The prevalence of *E. crus-galli* in DSR systems has been widely reported across major rice-growing regions of the world (Chauhan & Johnson, 2011).

During the early growth stages, *E. crus-galli* closely resembles rice seedlings in morphology, making visual discrimination difficult for farmers. Consequently, infestations are often recognised only after weeds have already caused significant yield losses. In Malaysia, yield reductions of up to 41% due to *E. crus-galli* infestation have been reported (Tosiah et al., 2009). In addition to yield suppression, this species has been identified as one of the most damaging weeds in rice systems, capable of severely depleting soil nitrogen by as much as 80%, and thereby reducing overall crop productivity (Hamza et al., 2012). The accumulation of high nitrate concentrations in *E. crus-galli* biomass may also pose potential risks to livestock health.

Water management practices further exacerbate weed problems in DSR systems. Limited or intermittent flooding favours weed emergence and growth, increasing dependence on both pre- and post-emergence herbicides (Chauhan & Johnson, 2010). In contrast, prolonged flooding in TPR systems suppresses many weed species and confers a competitive