Chapter 1

Introduction

1.1 Background

In the agricultural sector, weed infestations have long been a major threat. Weeds generally compete with crops for resources, slowing crop growth. The accumulation of these unwanted plants causes multiple issues, including reduced biodiversity, environmental destabilization, declines in crop quality, and increased production costs, which, if left untreated, can lead to food scarcity and economic losses (Blejan & Ionescu, 2024). One approach to counter this problem is to use herbicides. Herbicides control weeds, allowing crops to thrive in the field and leading to higher yields (Gao & Su, 2024). However, herbicide dependence can drive the evolution of herbicide-resistant weeds, enabling them to survive and making the approach no longer viable (Kodali et al., 2024). This condition occurs through an evolutionary mechanism within the weed population, in which a genetic mutation counteracts the herbicide's mode of action, allowing it to survive the inhibition and reproduce (Arasan et al., 2025). To reduce the risk of herbicide resistance in weeds, combining two or more herbicides is a promising approach that provides multiple modes of action that can reduce evolutionary pressure from chemical control (Diggle et al., 2003).

However, combining two different herbicides may result in either enhanced (known as synergism or additivism) or decreased (known as antagonism) effectiveness. Synergistic effect is achieved when a herbicide combination produces greater effectiveness than the sum of its individual effects (Cokol et al., 2011; Xu et al., 2024). Furthermore, most studies have shown that herbicide combinations produce antagonistic effects that reduce herbicide effectiveness (Merritt et al., 2020). Despite the downside, discovering a synergistic herbicide could significantly improve crop yields, reduce overall dosage and costs, and minimise environmental damage.

In this experiment, three herbicides were used: clomazone, imazapic, and paraquat. Imazapic works by inhibiting the acetolactate synthase (ALS) enzyme in plants, which is responsible for the biosynthesis of branched amino acids (Valine, Leucine, and Isoleucine) required for protein synthesis and growth (Chen et al., 2021). Clomazone targets 1-deoxy-D-xylulose-5-phosphate synthase (DXS) in the methylerythritol phosphate (MEP) pathway by producing 5-keto clomazone, a cytochrome P450 oxidation derivative that reduces chloroplast-bound isoprenoids in plants (Ferhatoglu & Barrett, 2006; Yasuor et al., 2010). Paraquat targets the photosystem I (PSI) in the photosystem electron transport chain. It uses electrons from ferredoxin to drive ferredoxin-nicotiamide Adenine Dinucleotide Phosphate ($NADP^+$) reductase (FNR), which ultimately feeds electrons into molecular oxygen (O_2), generating reactive oxygen species (Kim et al., 2026).

These herbicides were selected based on previous research by Sulaiman et al. (2024), which employed different *in silico* analyses to suggest potential synergistic effects among nine different herbicide modes of action commonly found in the Indonesian market. Their results indicated that clomazone-paraquat and imazapic-paraquat pairs are potentially synergistic combinations. However, no wet lab experiments were conducted to assess synergistic effects between herbicide combinations tested, underscoring the novelty of this experiment. For that reason, this study was proposed to understand the potential synergistic effects of clomazone-paraquat and imazapic-paraquat pairs in model dicotyledonous and monocotyledonous plants.

1.2 Objective

The objectives of this study included:

- To evaluate the synergistic effect of clomazone and imazapic when combined with paraquat.
- To calculate the sublethal concentration of the synergistic pair.

1.3 Hypothesis

The hypotheses in this study included:

H0: There is a synergistic effect found between clomazone and paraquat herbicide combinations, and between Imazapic and paraquat herbicide combinations.

H1: There is no synergistic effect found between clomazone and paraquat herbicide combinations, and between imazapic and paraquat herbicide combinations.