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Evaluating the Efficiency of Metsulfuron-Methyl: The Role of Rice Cultivation Practices in Controlling *Monochoria vaginalis*

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Abstract

Monochoria vaginalis is an invasive weed that thrives in rice paddies across Indonesia. Herbicide control is challenging since Monochoria vaginalis is known to be sulfonylurea-resistant in Indonesian rice fields. This weed is highly competitive, with a rapid growth pattern that may diminish rice production. Metsulfuron-methyl, a widely used herbicide, can potentially eliminate sensitive weeds at low dosage levels. This study aimed to identify the optimal dosage of metsulfuron-methyl for controlling *Monochoria vaginalis* and assess the impact of monoculture rice growing patterns and herbicide application in controlling weeds. The experimental design was a split-plot design with four replications, conducted from June to July 2023 in the Cikabayan Greenhouse at IPB University. The major plot was the *Monochoria vaginalis* accession: exposed or not exposed to herbicide, consisting of seven sites. The subplot represented the dosage of the active ingredient (a.i.) metsulfuron-methyl: 0, 1, 2, 4, 8, 16, and 32 g per ha. In addition to the field experiments, interviews were performed with five farmers from each of the seven *Monochoria vaginalis* sample accessions to assess rice planting patterns and herbicide usage history. The results showed that metsulfuron-methyl at 1 g.ha^{-1} reduced weed populations by over 50% in rice accessions Bugel, Palumbonsari, and Ciasem Hilir. Variability in *Monochoria vaginalis* indicated resistance to metsulfuron-methyl, necessitating greater dosages up to 8 g a.i. per ha^{-1} for Pasirkaliki and Rancajaya accessions. Our study also indicated that some areas could use lower dosages of herbicides to effectively control *Monochoria vaginalis*. In contrast to other places that required larger, three-yearly dosages of 100 to 125 g.ha^{-1}, Bugel, Palumbonsari, and Ciasem Hilir used a twice-yearly dosage of 20 g.ha^{-1}. These findings highlight the importance of tailored herbicide application strategies based on local resistance patterns and historical herbicide use to manage *Monochoria vaginalis* effectively.

Keywords: acetolactate synthase, dosage, monoculture, noxious weed, phytotoxicity.

Introduction

Weeds are a major impediment to the growth of cultivated plants. According to Oliveira et al. (2022), competition with weeds are the primary issue in rice production, accounting for around 30% of total losses. Weeds were estimated to cause yield losses of 50-91% for direct-seeded rice (Sen et al., 2021) and 64% for transplanted rice (Biswas et al., 2020). *Monochoria vaginalis*, an annual or perennial member of the Pontederiaceae family, is one of the significant lowland rice weeds. Both its vegetative and reproductive structures show great morphological variation (Setiawan and Sintadevi 2021). *Monochoria vaginalis* can decrease rice yield by up to 82%, and at a weed density of 150 per m^2, it can reduce rice yields by about 25% (CABI 2024). *Monochoria vaginalis* has the maximum weed dominance in paddy fields in Subang, West Java, with a total dominance value of 35.89% (Evar et al., 2022), followed by 26.90% in Semarang, Central Java (Utami and Purdyaningrum 2012), and 4.05% in Malang, East Java (Simanjuntak et al., 2016). *Monochoria vaginalis* reduces rice plant height, number of tillers, photosynthetic rate, leaf area, biomass, percentage of filled grain, and yield, due to competition, resulting in yield losses of up to 15% in Indonesia (Sulaiman and Guntoro 2022) and 45% in China (Zhou et al., 2021).

Beltran et al. (2013) reported that using herbicides was 80% more profitable than manual weeding. However, its effectiveness is impacted by herbicide application rates and varying weed species based on climate and soil (Sen et al., 2021). Metsulfuron-methyl is a selective pre- and post-emergence systemic herbicide that affects both foliage and soil and is widely used in lowland rice-producing areas.

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Metsulfuron-methyl has high herbicidal activity even at low application rates. Metsulfuron-methyl suppresses cell division in shoots and roots by inhibiting the enzyme acetolactate synthase (ALS) (Khairuddin et al., 2021). Acetolactate synthase (ALS) is an enzyme that targets five types of herbicide chemical compounds: pyrimidinyl-thiobenzoates (PTB), imidazolinone (IMI), triazolopyrimidine (TP), sulfonylamino-carbonyl-triazolinone (SCT), and sulfonylurea (SU) (Ottis et al., 2004). Plants perish if they lack these critical amino acids, as proteins cannot be produced. The ALS enzyme (E.C. 2.2.1.6) catalyzes the first step in the biosynthesis of the branched-chain amino acids valine (Val), leucine (Leu), and isoleucine (Ile) by inhibiting the conversion of ketoglutarate to 2-acetohydroxybutyrate and pyruvate to 2-acetolactate (Xu et al., 2020).

Monochoria vaginalis resistance to the herbicide bensulfuron-methyl (ALS inhibitor) has been confirmed in West Java (Widianto et al., 2022). Starting with the importance of the problem of resistant weeds and the potential negative consequences, research into testing the efficacy dosage of *Monochoria vaginalis* weeds from West Java against another sulfonylurea commonly used in rice fields, such as metsulfuron-methyl, is required to determine the effective dosage of metsulfuron-methyl in controlling *Monochoria vaginalis* broadleaf weeds. Over-reliance on herbicides and a lack of crop operations range in the rice system have resulted in significant selection for the evolution of resistant weed populations (Calha et al., 2022). The primary purpose of this research was to determine the optimal dosage required to manage the *Monochoria vaginalis* weed in each given site and to determine how monoculture rice planting density, herbicide treatment frequency, and metsulfuron-methyl dosage influence its efficacy at those sites.

Material and Methods

The study was conducted from June to July 2023 in the Cikabayan Greenhouse of the IPB University, Darmaga, West Java. First, a field survey was conducted to gather information on the spread of *Monochoria vaginalis*, which was assumed to be resistant to herbicides containing the active component metsulfuron-methyl. The field survey comprises conducting interviews with 35 farmers, 5 farmers each from a total of 7 coordinate samples of *Monochoria vaginalis*, to gather historical land usage data such as land areas, cropping system, application frequency, concentration (g.L^{-1}), and dosage (g.ha^{-1}) of metsulfuron-methyl. Historical land use data from Burgos (2015) contains GPS coordinates of the weed origin place, herbicide history, land area, planting style, and land use period.

The experimental design consisted of a split-plot with two components and four replications. The first factor is the *Monochoria vaginalis* accessions, which include seven major plots (Table 1). Sensitive *Monochoria vaginalis* seed samples were collected from herbicide-free rice fields in Tambakdahan, Subang (6°21’39.9”S, 107°48’07.8”E) (Widianto et al., 2022). Weed seeds are planted at a rate of 10-30 per pot and allowed to develop up to 20 weeds per pot.

The second component was the dosage level, which had seven values as subplot: 0, 1, 2, 4, 8, 16, and 32 g a.i. per ha. The herbicide dosage were 0, 0.25x, 0.5x, 1x, 2x, 4x, and 8x the recommended dosage of metsulfuron-methyl 20 WG. The recommended dosage is the application rate advised by manufacturers and the quantity listed on the label once it has been shown safe and effective in a certain environment (Denux et al., 2024). The recommended dosage of metsulfuron-methyl 20 WG is 20 g.ha^{-1}. Given that metsulfuron-methyl 20 WG contains 20% metsulfuron-methyl, the active ingredient applied per hectare is calculated as follows: 20 g.ha^{-1} × 0.20 = 4 g a.i. per ha. Thus, applying 20 g.ha^{-1} of metsulfuron-methyl 20 WG translates to 4 g a.i. per ha (FMC Corporation 2022)

Thus, 49 treatment combinations were created and repeated four times to obtain 196 experimental units. Data was analyzed using test F, followed by DMRT at 5% level. *Monochoria vaginalis* was treated with herbicide at 2 weeks after planting (WAP) (Widianto et al., 2022). Herbicides were applied as a foliar spray to a 2 x 2 m plots using a Bengawan Solo 425

Table 1. *Monochoria vaginalis* sampling accessions

Province	Regency	District	Village	Coordinate
Jawa Barat	Indramayu	Patrol	Bugel	6°18’53.0”S 108°00’19.2”E
	Indramayu	Sukra	Sumuradem	6°18’41.2”S 107°58’46.2”E
	Karawang	Rawamerta	Pasirkaliki	6°15’12.7”S 107°20’30.3”E
	Karawang	Karawang Timur	Palumbonsari	6°18’22.0”S 107°19’35.4”E
	Subang	Patokbeusi	Rancajaya	6°20’54.6”S 107°38’51.4”E
	Subang	Ciasem	Ciasem Hilir	6°18’30.6”S 107°42’56.5”E

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Compression Sprayer with a 15 L capacity, a Lurmark flat fan green nozzle (1.2 $L.min^{-1}$), and a spray volume of 400 $L.ha^{-1}$.

Weed dry weight data were acquired by harvesting 5 weed plants per plastic container (Widianto et al., 2022), with changes at 2 weeks after application (WAA). Weeds were dried in an oven at 80°C for 48 hours until the dry weight was consistent (Kurniadie et al., 2021). The percent damage value was determined by the following formula:
Percent damage (%) = (1-(P/K)) X 100%.
where
P = dry weight value of weeds with herbicide treatment
K = dry weight value of control weeds (Day and Pandit et al., 2020).

Result and Discussion

Phytotoxic Effects of Metsulfuron-Methyl on Monochoria vaginalis

The effect of metsulfuron-methyl application on poisoning symptoms of weeds exposed to and not exposed to herbicides produced diverse results. At 2 weeks after application, *Monochoria vaginalis* sensitive poisoning causes stunting or stunted development, yellowing of the leaves (chlorosis), necrosis, and mortality at 0.25-8x the recommended dosage of metsulfuron-methyl. *Monochoria vaginalis* accesion from Sumuradem, Bugel, Palumbonsari, and Ciasem Hilir at 1x the recommended dosage of metsulfuron-methyl (4 $g.ha^{-1}$) showed signs of poisoning ranging from chlorosis to necrosis Figure 1). A study by Marinangeli et al. (2010) described symptoms herbicide toxicities, including chlorosis, color changes, nastic organ development, and tissue necrosis. Poisoning symptoms,such as stunted development, discolored leaves, and short roots, would appear several days after ALS herbicide treatment, and the weeds will die within 2-4 weeks of application (Marble, 2016).

Chlorosis was observed in *Monochoria vaginalis* accession from Pasirkaliki after two applications of the acceptable dosage of 8 $g.ha^{-1}$, followed by necrosis after four applications of the recommended dosage of 16 $g.ha^{-1}$ (Figure 1). A previous study reported that pesticide application to *Sphenoclea zeylanica* was less harmful, which is consistent with Prakoso et al. (2018) findings. Even at the highest dosage of 128 $g.ha^{-1}$, *Sphenoclea zeylanica* demonstrated mild toxicity, similar to those exposed to low levels of metsulfuron-methyl.

In contrast, sensitive *Sphenoclea zeylanica* showed severe toxicity to metsulfuron-methyl at dosages ranging from 8 to 128 g a.i. per ha. *Echinochloa crus-galli* accession from East Karawang only experienced chlorosis when treated twice the recommended dosage (8 $g.ha^{-1}$); necrosis occurred at eight times

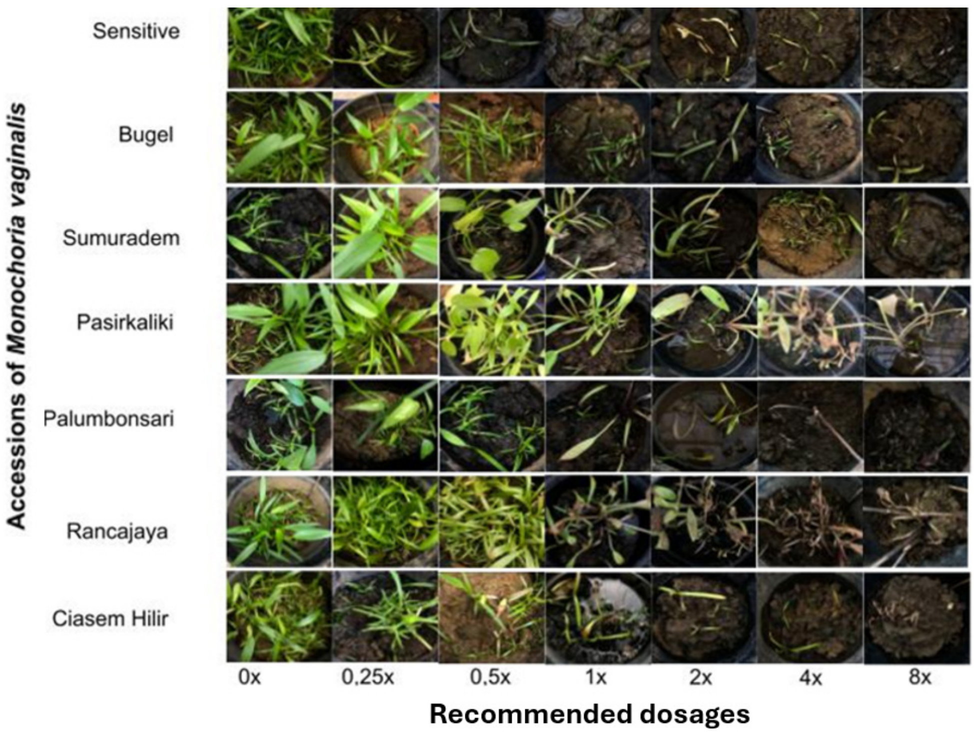

Figure 1. Symptoms of toxicity of various accessions of *Monochoria vaginalis* two weeks after the application of metsulfuron-methyl application.

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the recommended dosage (32 g.ha^{-1}), in contrast to the sensitive *Echinochloa crus-galli*, which died after treated with 1-8x the recommended dosage (Kurniadie et al., 2021). When the 4 g.ha^{-1} was given, the *Monochoria vaginalis* accession from Pasirkaliki, Karawang, showed higher growth compared to other *Monochoria vaginalis* genotypes, with more weed plants survived compared to the sensitive *Monochoria vaginalis* weed, which had already died (Figure 1). Metsulfuron-methyl at a concentration of 5 g.L^{-1} and a spray volume ranging from 193.75 L.ha^{-1} to 775 L.ha^{-1} has a two-year persistence in soil and can be metabolized by the soil microorganisms (Umiyati and Denny , 2018).

The Dry Weight of Monochoria vaginalis towards Metsulfuron-Methyl

Monochoria vaginalis weeds treated with herbicides had a higher average dry weight than those not exposed. The sensitive accession has a lower average dry weight (0.01 g) than Pasirkaliki (0.08 g), Rancajaya (0.07 g), Bugel (0.03 g), and Sumuradem (0.03 g) when treated with the recommended dosage of metsulfuron-methyl (4 g.ha^{-1}). *Monochoria vaginalis* from Pasirkaliki at 4 times the recommended dosage (16 g a.i. per ha^{-1}) had the greatest average dry weight (0.03 g) and was statistically different from others (Table 2).

The Percentage Damage of Monochoria vaginalis towards Metsulfuron-Methyl

The study found that the dosage level and provenance of the weed accessions had a substantial impact on the proportion of harm to *Monochoria vaginalis*. According to the findings in (Table 3,) the recommended dosage of metsulfuron-methyl (4 g.ha^{-1}) is effective in controlling sensitive *Monochoria vaginalis* accession. In reality, the damage percentage rate rose to 93.65%. This is in contrast to the *Monochoria vaginalis* accession from Pasirkaliki, where the effect of the herbicide dosage is limited, with an average level of damage percentage of 48.33% at 1x the recommended dosage of metsulfuron-methyl (4 g.ha^{-1}), and only 63.33% at 2x the recommended dosage of metsulfuron-methyl (8 g.ha^{-1}), and was significantly different from other locations.

Rice Cultivation Practices on the Efficacy of Metsulfuron-Methyl

According to farmer interviews, each site has a unique rice cultivation strategy that uses different herbicides (Table 4). In Ciasem, Palumbonsari, Bugel, and Sumuradem, the weed *monochoria vaginalis* can be efficiently managed with a recommendeddosage of 4 g a.i. per ha, resulting in a poisoning percentage of over 75%. These four regions feature a cultivation strategy that involves planting rice twice a year and applying herbicides 2 times successively (Table 4). Meanwhile, when the recommended amount of 4 g.ha^{-1} was administered to *Monochoria vaginalis* in Pasirkaliki and Rancajaya, the poisoning rate had not yet reached 50%. This suggests that metsulfuron-methyl is less effective for both *Monochoria vaginalis* in this area and requires a dosage twice as high as the recommended amount to kill 50% of the population, i.e. 8 g.ha^{-1}.

Table 2. The above-ground dry weight (grams) of *Monochoria vaginalis* accessions

Dosage (g.ha^{-1})	Accession						
	Sensitive	Bugel	Sumuradem	Pasirkaliki	Palumbonsari	Rancajaya	Ciasem Hilir
	(g)	(g)	(g)	(g)	(g)	(g)	(g)
0	0.16a	0.15a	0.14a	0.15a	0.15a	0.15a	0.14a
1	0.04b	0.07b	0.09b	0.11b	0.06b	0.09b	0.05b
2	0.02c	0.04c	0.06c	0.09c	0.03c	0.08c	0.02c
4	0.01d	0.03d	0.03d	0.08d	0.01d	0.07d	0.01d
8	0.01d	0.02e	0.02e	0.06e	0.01d	0.03e	0.01d
16	0.01d	0.01f	0.01f	0.03f	0.01d	0.02f	0.01d
32	0.01d	0.01f	0.01f	0.02g	0.01d	0.01f	0.01d

Note: Different letters within one column show significant differences according to the Duncan multiple range test at α=0.05. Metsulfuron-methyl dosages are based on the active ingredient (a.i.).

Sphenoclea zeylanica treated with metsulfuron-methyl could only be controlled at a dosage of 32 g.ha^{-1}, but sensitive *Sphenoclea zeylanica* died at dosages of 2, 4, 8, and 16 g.ha^{-1} (Rahmadi et al., 2014). Exposed *Sphenoclea zeylanica* has more biomass than unexposed *Sphenoclea zeylanica*. This is consistent with the findings of McCullough et al. (2016), who reported that resistance to ALS herbicides will reduce weed biomass. According to Costa and Rizzardi (2014), the resistant *Raphanus raphanistrum* weed had a significantly higher dry weight than the sensitive one.

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Table 3. Percentage of damage (%) of *Monochoria vaginalis* accessions after being treated with metsulfuron-methyl

Dosage ($g.ha^{-1}$)	Accession						
	Sensitive	Bugel	Sumuradem	Pasirkaliki	Palumbonsari	Rancajaya	Ciasem Hilir
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
0	0.00d	0.00e	0.00f	0.00f	0.00d	0.00f	0.00d
1	74.58c	52.29d	35.71e	26.67e	60.00c	37.86e	63.60c
2	87.29b	73.75c	57.14d	38.33d	80.00b	44.76d	83.52b
4	93.65a	82.81b	76.79c	48.33c	91.67a	49.88c	92.72a
8	93.65a	86.88b	85.71b	63.33b	91.67a	82.74b	92.72a
16	93.65a	93.44a	91.07a	81.67a	91.67a	89.64a	92.72a
32	93.65a	93.44a	92.86a	90.00a	93.33a	93.10a	92.72a

Note: Different letters within one column show significant differences according to the Duncan multiple range test at α=0.05. Metsulfuron-methyl dosages are based on the active ingredient (a.i.).

Table 4. History of metsulfuron-methyl uses at seven locations of rice fields to control *Monochoria vaginalis*

Locations	Cropping system in a year	Land area (ha)	Frequency application of metsulfuron-methyl in a year	Concentration of metsulfuron-methyl ($g.L^{-1}$)
Sensitive	Rice-Rice	0.38	0	0.00
Bugel	Rice-Rice	1.00	2	0.05
Sumuradem	Rice-Rice	2.00	2	0.16
Pasirkaliki	Rice-Rice-Rice	2.00	3	0.31
Palumbonsari	Rice-Rice	1.60	2	0.04
Rancajaya	Rice-Rice-Rice	2.00	3	0.25
Ciasem Hilir	Rice-Rice	0.70	2	0,04

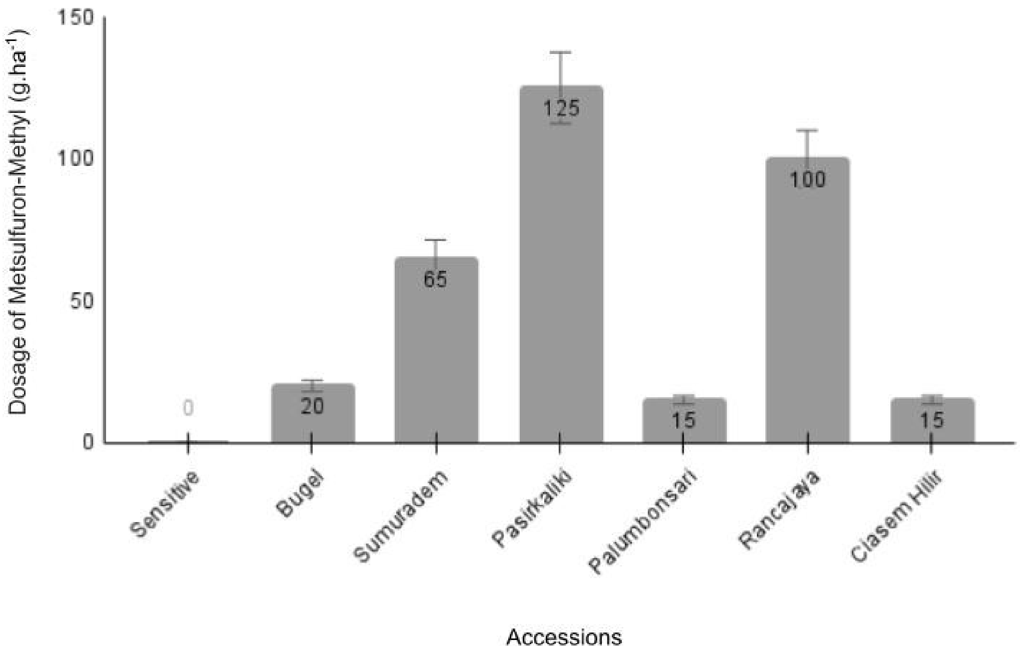

Figure 2. Dosage of metsulfuron-methyl ($g.ha^{-1}$) for each accession of *Monochoria vaginalis*.

According to the results of farmer interviews, rice planting intensity is higher in Pasirkaliki and Rancajaya, with a year-round planting pattern of rice-rice-rice, implying that rice plants are planted three times in the same year in both locations (Table 4). Most farmers grew rice in monocropping for at least five to ten years. Herbicides are not employed in sensitive control region. Furthermore, metsulfuron-methyl herbicide is applied more frequently in the Pasirkaliki and Rancajaya rice paddies than elsewhere, with three applications per year (Table 4). According to (Figure 2), The dosage of metsulfuron-

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methyl (g.ha^{-1}) used in various rice paddy locations shows different variations. Pasirkaliki farmers utilized the maximum dosage of 125 g.ha^{-1}, Rancajaya 100 g.ha^{-1}, Sumuradem 65 g.ha^{-1}, Bugel 20 g.ha^{-1}, while Palumbonsari and Ciasem Hilir used 15 g.ha^{-1}.

Discussion

The herbicide metsulfuron-methyl at a active ingredient dosage of 1-2 g.ha^{-1} causes symptoms of poisoning in *Monochoria vaginalis* from Sumuradem, Bugel, Palumbonsari, and Ciasem Hilir, such as chlorosis, necrosis, and death, beginning two weeks after application (Figure 1). This suggests that the herbicide metsulfuron-methyl effectively inhibits the ALS enzyme at the access point. The herbicide metsulfuron-methyl works systemically by transporting it through the xylem and phloem and inhibiting the acetolactate synthase enzyme, which prevents the production of the three amino acids, valine, leucine, and isoleucine, thereby inhibiting plant shoot and root cell division. The sulfonylurea herbicide (metsulfuron-methyl) reduces ALS indirectly by reducing DNA synthesis, which inhibits the feedback function of ribulose diphosphate reductase (RDP). The herbicide lowers the active molecule thiamine diphosphate (ThDP) in cells, therefore inhibiting the effectiveness of ALS therapies. ThDP is a cofactor for the ALS enzyme, which generates energy for cell division and all metabolic processes in plant cells. Reducing ThDP inhibits the synthesis of the amino acid leucine, isoleucine, and valine. If ThDP requirements are not met, growth might be impeded as indicated by signs such as yellowing, necrosis, and impaired root formation (Garcia et al., 2017).

Metsulfuron-methyl, starting with a modest a.i. dosage of 1 g.ha^{-1}, reduced the biomass of *Monochoria vaginalis* from Bugel, Palumbonsari, and Ciasem Hilir (Table 2). Consequently, 1 g.ha^{-1} is the optimal dosage for such regions. The quantity of herbicide that effectively controls weeds while having the fewest detrimental effects on crops, the environment, and human health is known as the optimal herbicide dosage. It ensures sustainable farming operations by striking a balance between efficacy and safety (P2019). The capacity of metsulfuron-methyl to inhibit the development of the ALS enzyme was associated to the decrease in weed dry weight. *Monochoria vaginalis* metabolism is disturbed, resulting in toxicity and potentially death. In some situations of resistant weeds, inhibiting ALS enzyme synthesis disrupts protein creation and photosynthetic transmission, resulting in reduced weed biomass and seed yield. In general, weeds exposed to herbicides had a lower average reduction in weed growth than weeds not exposed to herbicides. The higher the herbicide dosage, the greater the inhibitory effect on weed growth, which results in a decrease in dry weight (Majd et al., 2019). Using higher dosages above the recommended dosage, such as 16 g.ha^{-1}, can kill weeds with a dry weight of 0.01 gram for *Monochoria vaginalis* from Bugel, Sumuradem, Palumbonsari, and Ciasem Hilir. The ability of metsulfuron-methyl to inhibit the synthesis of the ALS enzyme is responsible for the reduction in weed dry weight. Inhibiting ALS enzyme development in *Amaranthus powellii* (Tardif et al., 2006) can lead to reduced biomass and seed production. Furthermore, a drop in dry weight shows that resistance to ALS inhibitors may result in a fitness cost in plant development in resistant *Limnocharis flava* populations (Zkaria *et al*. 2017).

The percentage of damage indicates how much the herbicide metsulfuron-methyl reduces the growth of *Monochoria vaginalis* in each place of origin (Table 3). Metsulfuron-methyl 20% at a dosage of 1 g.ha^{-1}significantly reduced *Monochoria vaginalis* populations from Bugel, Palumbonsari, and Ciasem Hilir by more than 50% (Table 3). This suggests that *Monochoria vaginalis* from this area can be managed with a.i. dosages lower than the prescribed amount of 4 g.ha^{-1}. However, *Monochoria vaginalis* from Pasirkaliki and Rancajaya requires up to two times the recommended a.i. dosage (8 g.ha^{-1}). *Monochoria vaginalis* weeds in herbicide-treated rice fields are more difficult to suppress than weeds in herbicide-free or low-herbicide-use areas. These results are consistent with the findings of other studies, which show that the percentage of damage to *Monochoria vaginalis* from Subang, Indonesia, which is resistant to the herbicide methyl bensulfuron (sulfonylurea), is 18.98%, which is less than the sensitivity of 100% at the recommended dosage of 4 g.ha^{-1} (Widianto et al., 2022). Furthermore, *Monochoria vaginalis* from Central Lampung showed a low damage percentage of 23.37% at a recommended level of 4 g a.i. per ha. This suggests that bensulfuron-methyl cannot suppress *Monochoria vaginalis* in Central Lampung at the recommended dosage (Widianto et al., 2022). Similarly, the *Echinochloa crus-galli* accession from East Karawang showed that the effect of the herbicide dosage was limited, with an average level of damage percentage of 31.15% at 1x the recommended a.i. dosage of metsulfuron-methyl (4 g.ha^{-1}) and only 64.30% at 4x the recommended a.i. dosage of metsulfuron-methyl (16 g.ha^{-1}) (Kurniadie et al., 2021).

According to data in Table 4, the effectiveness of *Monochoria vaginalis* response to the herbicide metsulfuron-methyl (sulfonylurea) depends on the frequency of using herbicides with the same mode

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of action, the dosage used in hectare, the cropping system (monoculture), and the frequency of planting per year. Rice fields that used low dosages of metsulfuron-methyl (Figure 2) with a monoculture rice planting frequency of twice a year, as well as herbicides applied only twice a year (Table 4), efficiently controlled the weed *Monochoria vaginalis* at dosage lower than the recommended dosage. Rice fields in Pasirkaliki and Rancajaya, on the other hand, required greater dosages to kill *Monochoria vaginalis* since they are typically treated with high dosages of 100 g.ha^{-1} and 125 g.ha^{-1} (Figure 2), as well as high planting frequency and herbicide applications each year, up to three times (Table 4). The findings are consistent with previous research, which discovered that the percentage of weed growth damage varies by location and is influenced by a variety of factors such as the history of land use, herbicide practices, herbicide use frequency, and cropping system used in each location where the weed originates (Kurniadie et al., 2021; Calha et al., 2022).This issue is highly related to the perception of herbicide resistance, other researchers have identified a accession of *Monochoria vaginalis* that is resistant to bensulfuron-methyl (sulfonylurea) with a ratio (R/S) of 31.28 in Indonesia (Widianto et al., 2022). As a result, metsulfuron-methyl continued to be effective for *Monochoria vaginalis* in rice fields with fewer than two herbicide applications with the same mode of action per year, using a different mode of action herbicide for pre- and post-emergence (herbicide rotation), using a lower dosage than recommended, and possibly using intercropping or multiple cropping. Combining environmental risk, efficacy, and economic data provides a significant decision-making tool for farmers to control weeds (Fillols et al., 2020). Further studies are required to gain more understanding on the resistance mechanisms to this herbicide.

Conclusion

The herbicide metsulfuron-methyl 20% at a dosage of 1 g.ha^{-1} effectively reduced *Monochoria vaginalis* population by more than 50% in sensitive, Bugel, Palumbonsari, and Ciasem Hilir accessions up to 2 weeks after application. *Monochoria vaginalis* from Sumuradem required 2 g.ha^{-1} and *Monochoria vaginalis* from Pasirkaliki and Rancajaya required 8 g.ha^{-1} metsulfuron-methyl to achieve a 50% reduction in populations, which is 8 times greater than the effective dosage for sensitive Bugel, Palumbonsari, and Ciasem Hilir accessions. Areas like Bugel, Palumbonsari, and Ciasem Hilir used metsulfuron-methyl twice yearly at lower dosage, i.e., 20 g.ha^{-1} in Bugel and 15 g.ha^{-1} for Palumbonsari and Ciasem Hilir. This approach effectively controls *Monochoria vaginalis* compared to Pasirkaliki, Rancajaya, and East Sumuradem, where higher dosages of 125 g.ha^{-1}, 100 g.ha^{-1}, and 65 g.ha^{-1}, respectively, are applied three times annually. The application time is related to the frequency of rice planting seaason throughout the year. Thus, optimizing herbicide application frequency and dosage proves crucial in managing this weed species in the rice fields.

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