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Suppression and regrowth inhibition of *Scleria sumatrensis* using systemic herbicides in Nunukan oil palm plantations

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ABSTRACT

Weed infestation in oil palm plantations can reduce crop productivity due to competition for nutrients, water, and sunlight. *Scleria sumatrensis*, commonly known as rija-rija weed, is one of the dominant weed species that is difficult to control because of its rapid growth and high adaptability in plantation areas. This study aimed to evaluate the effectiveness of several systemic herbicides in controlling rija-rija weed (*Scleria sumatrensis*) in *Elaeis guineensis* plantations. The research was conducted from March to April 2025 in Nunukan Regency, North Kalimantan, Indonesia. A Randomized Block Design (RBD) was applied using four systemic herbicide treatments, namely glyphosate, 2,4-D dimethyl amine, metsulfuron-methyl, and penoxsulam, with six replications for each treatment. The observed parameters included leaf wilting score, percentage of affected weeds, and weed regrowth after application. Data were analyzed using analysis of variance (ANOVA), followed by Tukey's Honestly Significant Difference (HSD) test at a 5% significance level. The results showed that glyphosate treatment provided the most effective suppression of *S. sumatrensis* compared to the other herbicides tested. Glyphosate produced the highest percentage of affected weeds, reaching 95.28% at 4 weeks after application (WAA), and resulted in the lowest weed regrowth percentage of 15.17%. In contrast, dimethyl amine and metsulfuron-methyl treatments showed lower effectiveness with higher weed regrowth, while penoxsulam exhibited a moderate control response. Overall, systemic herbicides were effective in suppressing the growth of rija-rija weed (*Scleria sumatrensis*) in oil palm plantations, with glyphosate identified as the most effective treatment.

INTRODUCTION

Elaeis guineensis is one of the most important plantation commodities in Indonesia due to its high economic value [1]. It also makes a major contribution as a source of vegetable oil for food, industrial products, and renewable energy [2]. The expansion of plantation areas and the increase in oil palm production in North Kalimantan during recent years indicate that this commodity has strong potential for further development. Oil palm expansion has been associated with regional economic growth and improved rural socio-economic conditions in Kalimantan [3][4].

In oil palm cultivation, crop productivity is often affected by weed infestation. Weeds compete with cultivated plants for nutrients, water, sunlight, and growing space, which may reduce plant growth and yield [5][6]. In addition, several weed species can act as hosts for pests and plant diseases and may produce allelopathic compounds that negatively affect crop development. Therefore, effective weed management is essential to maintain plantation productivity [7][8].

One of the dominant weeds frequently found in oil palm fields is *Scleria sumatrensis*, a species from the Cyperaceae family characterized by rapid growth and high adaptability in open and swampy areas. The presence of rija-rija weed can suppress crop growth through competition for nutrients and water, particularly nitrogen, thereby requiring effective control measures. Moreover, its sturdy stem structure and dominant growth habit make this weed relatively difficult to control through mechanical methods or inappropriate herbicide applications. Several studies have identified *S. sumatrensis* as a problematic weed species that requires proper herbicide management to reduce its dominance and weed pressure [9][10]. Herbicide application may also alter weed community composition in mature oil palm plantations, highlighting the importance of selecting effective and sustainable weed control strategies [11]. Furthermore, improper and continuous herbicide use can contribute to herbicide resistance in plantation weeds [12].

Weed control in oil palm plantations is commonly carried out chemically using herbicides because this method is considered more practical, efficient, and labor-saving than manual or mechanical control methods [13]. The effectiveness of weed management is strongly influenced by the suitability of herbicide selection to the characteristics of the target weed species [12]. Systemic herbicides are widely used because their active ingredients can be translocated throughout weed tissues, including roots and growing points, resulting in more effective suppression [14]. Previous studies have demonstrated the effectiveness of systemic herbicides such as glyphosate and metsulfuron-methyl in controlling weeds in oil palm plantations [15][16].

Several systemic herbicides commonly applied in oil palm plantations include glyphosate, 2,4-D dimethyl amine, metsulfuron methyl, and penoxsulam. Glyphosate inhibits the 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) enzyme involved in the synthesis of essential amino acids, thereby disrupting

weed metabolism and growth [17]. Meanwhile, 2,4-D dimethyl amine acts as a selective systemic herbicide that mimics plant growth hormones, resulting in abnormal growth in susceptible weeds [18]. Metsulfuron methyl and penoxsulam belong to the acetolactate synthase (ALS)-inhibiting herbicide group, which interferes with the biosynthesis of branched-chain amino acids in plants [19][20]. Continuous use of ALS-inhibiting herbicides may also contribute to herbicide resistance through mutations in the ALS gene [21].

Despite the widespread use of systemic herbicides in oil palm plantations, information regarding their comparative effectiveness in controlling *Scleria sumatrensis* remains limited, particularly under the environmental and land conditions of North Kalimantan. In addition, studies evaluating different herbicide active ingredients with distinct modes of action against this weed species are still scarce. Therefore, this study was conducted to evaluate the effectiveness of several systemic herbicides in controlling rija-rija weed (*Scleria sumatrensis*) in oil palm plantations and to identify the most effective active ingredient for suppressing weed growth.

MATERIALS AND METHODS

Research site

The research was conducted from March to April 2025 in an *Elaeis guineensis* plantation area owned by PT FAP AGRI Tbk located in Nunukan Regency, North Kalimantan, Indonesia. The study site was selected because it had a relatively uniform infestation of *Scleria sumatrensis* within the observation plots. The research consisted of several stages, including preparation, experimental implementation, and data analysis (Figure 1). Weed identification was carried out to confirm the target weed species used in the experiment. Experimental plots were subsequently arranged using a Randomized Block Design (RBD) consisting of four systemic herbicide treatments with six replications.

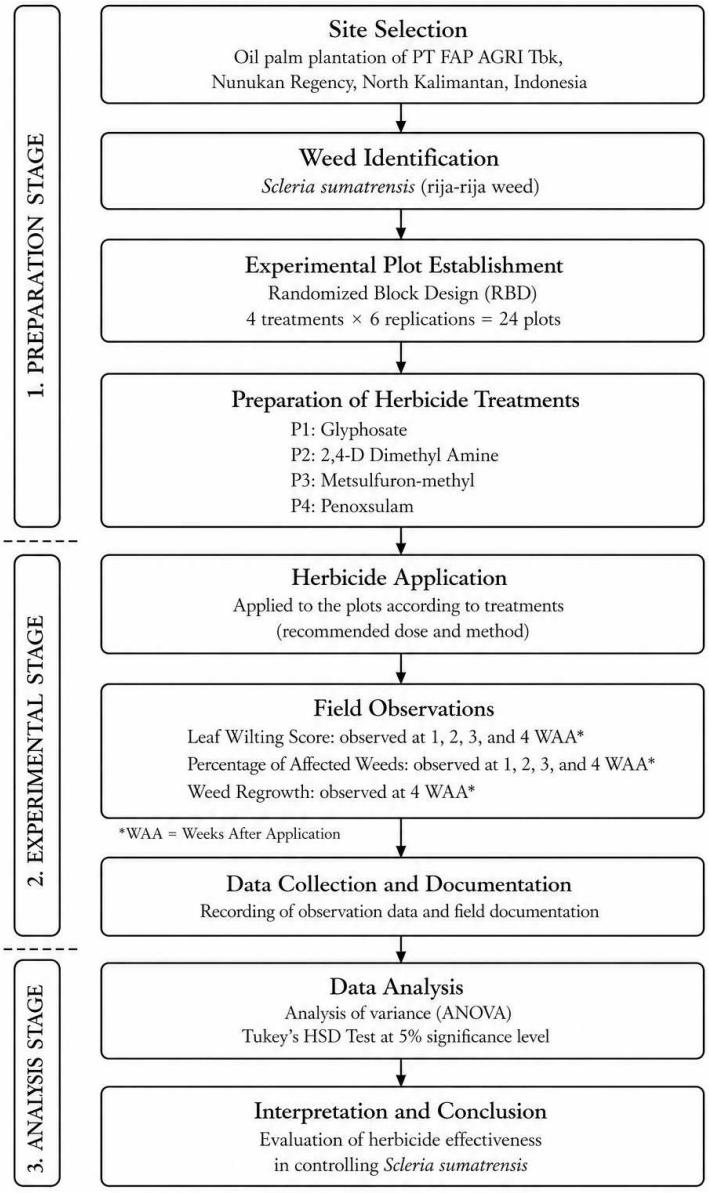


Figure 1. Conceptual flowchart of the research stages for evaluating the effectiveness of systemic herbicides in controlling *Scleria sumatrensis* in oil palm (*Elaeis guineensis*) plantations.

Materials and equipment

The materials used in this study included several systemic herbicides with different active ingredients, namely glyphosate, dimethyl amine, metsulfuron methyl, and penoxsulam. Additional materials consisted of clean water and observation labels. The equipment used included a knapsack sprayer, measuring cup, analytical balance, camera, stationery, and supporting field observation tools.

Experimental design

The experiment was arranged using a Randomized Block Design (RBD) consisting of four systemic herbicide treatments with six replications. Each treatment represented a different herbicide active ingredient applied to the target weed population. The treatments

were as follows: P1 = glyphosate; P2 = dimethyl amine; P3 = metsulfuron methyl; and P4 = penoxsulam. Each experimental plot was arranged according to field conditions and separated to minimize spray contamination among treatments.

Herbicide application

Herbicide solutions were prepared according to the recommended dosage of each active ingredient. Application was carried out using a knapsack sprayer by evenly spraying the herbicide solution onto the weed canopy. Spraying activities were conducted in the morning under suitable weather conditions to minimize wind interference and herbicide wash-off caused by rainfall.

Observation parameters

Observations were conducted periodically after herbicide application. The observed parameters included leaf wilting score, percentage of affected weeds, and weed regrowth. Leaf wilting was visually assessed based on the level of chlorosis, necrosis, and leaf drying symptoms appearing after herbicide application. The percentage of affected weeds was calculated by comparing the number of weeds showing herbicide injury symptoms with the total weed population in each treatment plot. Weed regrowth was determined based on the emergence of new shoots or recovery of weed growth following herbicide application.

Data analysis

Data representation was tailored based on the characteristics of each parameter to maximize visual clarity. The leaf wilting scores (categorical-ordinal data over time) were visualized using a sequential heatmap matrix to trace chronological stress patterns. Meanwhile, quantitative parameters, including the percentage of affected weeds and average weed regrowth, were represented using graphical visualizations. All collected quantitative data were subjected to analysis of variance (ANOVA) at a 5% significance level. For parameters exhibiting significant treatment effects, the analysis was followed by Tukey's Honestly Significant Difference (HSD) test ($\alpha = 0.05$) to determine specific differences among the treatments. The resulting statistical groupings and mean values were embedded into the graphical labels of the corresponding charts.

RESULTS AND DISCUSSION

Leaf wilting score

The observation results showed that the application of several systemic herbicides produced different responses in the leaf wilting level of *Scleria sumatrensis*. Initial symptoms after herbicide application were characterized by chlorosis, followed by necrosis and tissue drying. Glyphosate treatment produced wilting symptoms more rapidly than the other treatments, indicating that the active ingredient was effectively absorbed and translocated throughout the weed tissues, thereby disrupting physiological and metabolic processes (Figure 2).

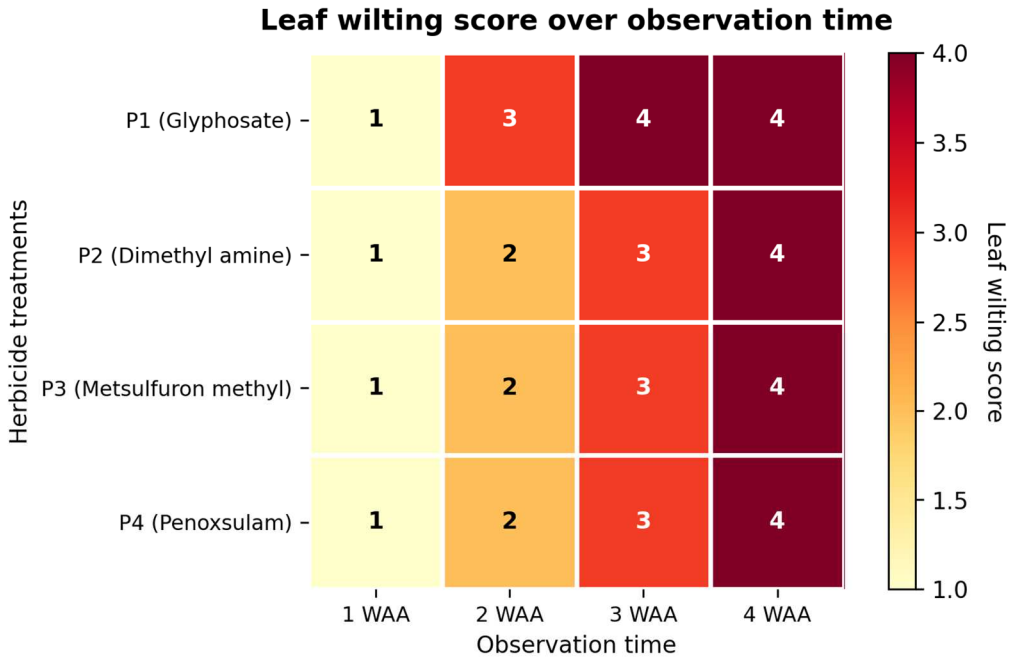


Figure 2. Leaf wilting scores of weed communities under various herbicide treatments. Note: P1 = glyphosate; P2 = dimethyl amine; P3 = metsulfuron methyl; P4 = penoxsulam; WAA = weeks after application.

At 1 Week After Application (WAA), all treatments showed the same wilting score of 1, indicating that the leaves remained green and fresh without visible herbicide injury symptoms. This condition suggested that the herbicides had not yet been fully translocated within plant tissues during the early stage after application. The absence of visible injury symptoms at this stage also indicated that the physiological processes of the weeds were still functioning normally despite herbicide exposure. At 2 WAA, glyphosate treatment (P1) exhibited the highest wilting score of 3, characterized by leaf yellowing, reduced turgor pressure, and the initial drying of leaf tissues. In contrast, dimethyl amine (P2), metsulfuron methyl (P3), and penoxsulam (P4) treatments showed a wilting score of 2, indicating relatively mild wilting symptoms. The more rapid symptom development in glyphosate-treated plants suggested that this herbicide had higher absorption and translocation efficiency in *S. sumatrensis* compared to the other herbicides tested. The faster response observed in glyphosate-treated plants was likely associated with the inhibition of the EPSPS enzyme, which interferes with the biosynthesis of essential aromatic amino acids required for normal plant growth and metabolism [17]. Disruption of amino acid synthesis reduces protein formation and accelerates tissue senescence, leading to earlier chlorosis and wilting symptoms.

At 3 WAA, the highest wilting score remained in the glyphosate treatment with a score of 4. Most leaves had dried, curled, and experienced tissue death. Meanwhile, treatments P2, P3, and P4 reached a wilting score of 3, indicating progressive injury symptoms although some leaf tissues still remained green. This result indicated that glyphosate was able to suppress weed physiological activity more rapidly and intensively than the other systemic herbicides. The slower symptom development in metsulfuron methyl and penoxsulam treatments may be related to their mode of action as acetolactate synthase (ALS)-inhibiting herbicides, which suppress the biosynthesis of branched-chain amino acids and gradually inhibit cell division and plant growth [19][20]. Herbicides belonging to the ALS-inhibitor group generally produce slower visible injury

symptoms compared to glyphosate because growth inhibition occurs progressively following metabolic disruption.

At 4 WAA, all treatments reached the same wilting score of 4, indicating complete leaf drying and severe tissue damage. This result suggested that all tested systemic herbicides were ultimately capable of suppressing the growth of *S. sumatrensis*, although the rate of symptom development differed among herbicide active ingredients. The similarity of final wilting scores among treatments indicated that prolonged exposure to systemic herbicides was sufficient to cause irreversible tissue damage and loss of physiological function in the weeds. Similar findings have been reported by Hirda et al. [15] and Rambe et al. [16], who demonstrated that systemic herbicides require time for absorption and translocation before causing maximum injury symptoms in weeds.

The differences in wilting responses among treatments suggest that weed control effectiveness was closely associated with the characteristics of each herbicide active ingredient, particularly its mode of action, translocation capacity, and the sensitivity of *Scleria sumatrensis* to the applied herbicides. This finding is consistent with previous studies reporting that herbicide performance is strongly influenced by active ingredient properties, translocation ability, and target weed susceptibility [12]. Systemic herbicides are absorbed through leaf tissues and subsequently translocated throughout the plant, causing physiological disturbances that eventually lead to chlorosis, necrosis, wilting, and plant death [14][22]. In addition, environmental conditions, plant morphology, and herbicide absorption efficiency may influence the rate and severity of herbicide injury symptoms [23].

Percentage of affected weeds

The observation results showed that the application of several systemic herbicides produced different responses to the percentage of affected weeds in *Scleria sumatrensis* during the observation period. Based on Tukey's HSD test at the 5% significance level, herbicide treatments significantly affected the percentage of affected weeds at 1 Week After Application (WAA), whereas from 2 to 4 WAA the treatment effects tended to show no significant differences (Figure 3).

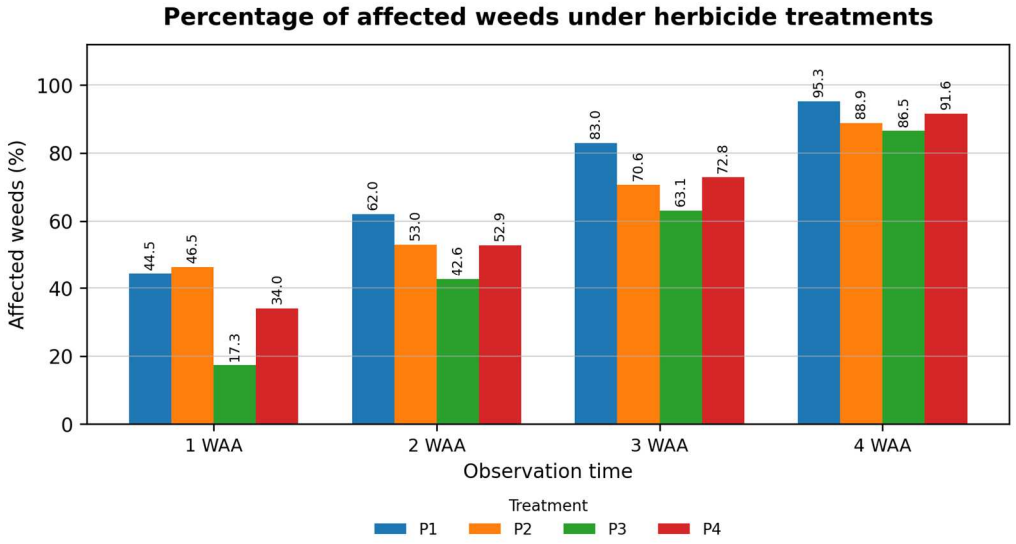


Figure 3. Percentage of affected weeds under various herbicide treatments. Note: P1 = glyphosate; P2 = dimethyl amine; P3 = metsulfuron methyl; P4 = penoxsulam; WAA = weeks after application.

At 1 WAA, glyphosate (P1) and dimethyl amine (P2) treatments resulted in the highest percentages of affected weeds, reaching 44.48% and 46.50%, respectively, and showed relatively similar responses. In contrast, metsulfuron methyl treatment (P3) produced the lowest percentage of affected weeds at 17.32%, while penoxsulam treatment (P4) showed a moderate control response with 34.00% affected weeds. The rapid increase in the percentage of affected weeds in glyphosate and dimethyl amine treatments indicated that these herbicides were able to interfere with weed physiological activity more quickly during the initial phase after application. This condition suggested that the active ingredients were rapidly absorbed and effectively translocated within plant tissues, resulting in earlier development of chlorosis and tissue injury symptoms. The lower percentage observed in metsulfuron methyl treatment also indicated that ALS-inhibiting herbicides generally require a longer period before visible injury symptoms appear because growth suppression occurs gradually following metabolic disruption. The higher percentage of affected weeds in glyphosate and dimethyl amine treatments indicated that these herbicides were able to induce visible injury symptoms more rapidly during the early stages after application. This response suggested that the active ingredients had faster absorption and translocation rates within weed tissues, resulting in quicker disruption of physiological processes. Similar results were reported by Hirda et al. [15], who found that glyphosate herbicide rapidly suppressed weed growth in immature oil palm plantations due to its systemic translocation characteristics. In addition, Umiyati et al. [18] stated that 2,4-D dimethyl amine effectively induced abnormal growth and tissue injury in susceptible broadleaf weeds through rapid hormonal disruption.

From 2 to 4 WAA, all treatments showed a progressive increase in the percentage of affected weeds. This trend indicated that systemic herbicides required time for translocation and accumulation within plant tissues before causing maximum injury symptoms. The gradual increase in weed injury also reflected the continued disruption of physiological and metabolic activities following herbicide absorption. As herbicide compounds were translocated to actively growing tissues, symptoms such as chlorosis, tissue drying, and growth inhibition became more apparent over time. At 4 WAA, glyphosate treatment still exhibited the highest weed control level at 95.28%, followed by penoxsulam at 91.63%, dimethyl amine at 88.88%, and metsulfuron methyl at 86.51%. The consistently high percentage of affected weeds observed in the glyphosate treatment suggested that this active ingredient had greater effectiveness in suppressing the growth of *S. sumatrensis* compared to the other herbicides tested. This condition also indicated that glyphosate was able to maintain herbicidal activity for a longer period, resulting in more extensive tissue damage and suppression of weed recovery. Similar findings were also reported by Rambe et al. [16], who demonstrated that glyphosate-based herbicide mixtures provided effective weed suppression in oil palm plantations due to efficient absorption and translocation within weed tissues.

Differences in treatment responses were likely influenced by the mode of action of each herbicide active ingredient. Variations in

herbicide performance indicated that each active ingredient interacted differently with the physiological characteristics of *S. sumatrensis*, resulting in differences in the rate of injury development and weed suppression. Glyphosate acts systemically by inhibiting the synthesis of essential amino acids, thereby disrupting plant metabolic processes and suppressing weed growth [17]. The rapid injury symptoms observed in glyphosate-treated weeds suggested that inhibition of amino acid synthesis quickly affected cellular activity and reduced the ability of weeds to maintain normal physiological functions. Meanwhile, metsulfuron methyl and penoxsulam require translocation to the growing points before visible injury symptoms can develop optimally. Herbicides belonging to the ALS-inhibiting group generally produce slower visible symptoms because growth suppression occurs gradually following metabolic disruption [19][20]. This gradual response indicated that ALS inhibition initially affected cell division and new tissue formation before visible damage became apparent on older tissues. The effectiveness of systemic herbicides is also influenced by weed physiological conditions, plant age, environmental factors, and application accuracy. Under active growth conditions, herbicide absorption through leaf tissues occurs more efficiently, allowing effective translocation to meristematic tissues [14][22].

Weed regrowth

The results showed that systemic herbicide treatments affected weed regrowth after application. Glyphosate treatment resulted in the lowest percentage of weed regrowth, reaching 15.17%. This finding indicated that glyphosate was more effective in suppressing weed regrowth compared to the other treatments. The lower regrowth observed in the glyphosate treatment suggested that the active ingredient was able to suppress not only the aboveground tissues but also the underground growing points responsible for weed regeneration. This condition indicated that glyphosate provided more prolonged control activity, thereby reducing the ability of *S. sumatrensis* to recover after herbicide exposure (Figure 4).

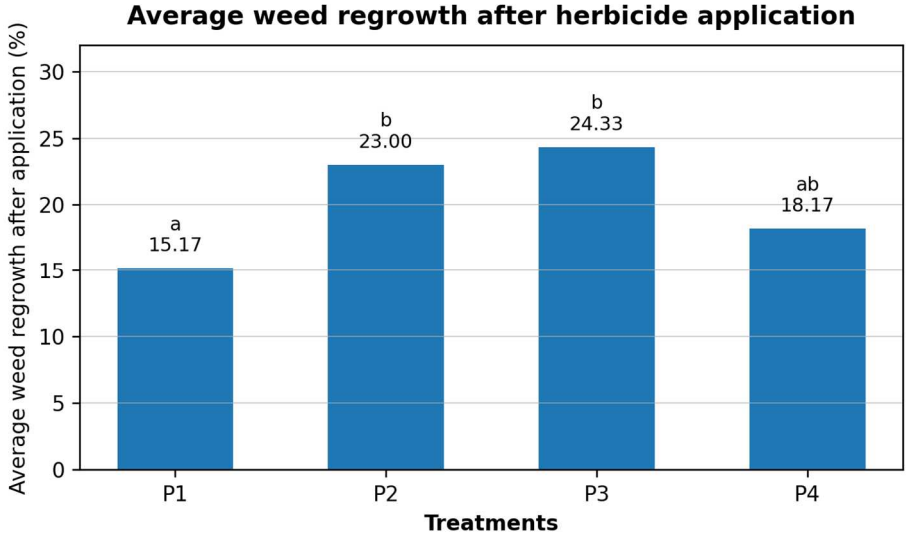


Figure 4. Average weed regrowth after herbicide application. Note: P1 = glyphosate; P2 = dimethyl amine; P3 = metsulfuron methyl; P4 = penoxsulam. Means followed by the same letter are not significantly different according to Tukey's HSD test at the 5% significance level.

The low regrowth observed in the glyphosate treatment was likely due to the ability of the active ingredient to reach the roots and growing points, thereby inhibiting weed regeneration. Glyphosate is known to be effectively translocated through the phloem into meristematic tissues, causing disruption of amino acid synthesis and inhibition of new tissue formation [17][22]. In contrast, dimethyl amine and metsulfuron methyl treatments still showed the emergence of new shoots in several weeds after application. This response indicated that some weed tissues were still physiologically active and capable of initiating regrowth after the initial herbicide injury. Penoxsulam provided a moderate effect in suppressing weed regrowth. Herbicides belonging to the ALS-inhibiting group generally suppress plant growth gradually, so visible tissue death and regrowth inhibition may require a longer period to develop completely [19][20].

The ability of systemic herbicides to suppress weed regrowth is important in weed management in *Elaeis guineensis* plantations because it can reduce the frequency of weed control and maintenance costs. Effective suppression of weed regrowth also helps minimize competition for nutrients, water, and sunlight during the critical growth period of oil palm plants. Similar findings were reported by Rambe et al. [16], who stated that systemic herbicides with effective translocation characteristics were able to provide longer weed suppression in oil palm plantations. The appropriate selection of herbicide active ingredients is expected to improve the efficiency of sustainable weed management practices.

Overall, the use of systemic herbicides was effective in suppressing the growth of *Scleria sumatrensis* in oil palm plantations. Differences in treatment effectiveness indicated that each active ingredient had a different level of control against the target weed. Variations in herbicide performance were likely associated with differences in herbicide absorption, translocation efficiency, and physiological sensitivity of weeds to each active ingredient. Glyphosate was identified as the most effective treatment based on leaf wilting score, percentage of affected weeds, and low weed regrowth.

The results of this study indicate that selecting the appropriate herbicide active ingredient plays an important role in the success of weed control in the field. Effective use of systemic herbicides can reduce competition between weeds and oil palm plants for nutrients, water, and sunlight, thereby supporting more optimal crop growth. In addition, proper herbicide selection may contribute to more efficient and sustainable weed management by reducing repeated applications and minimizing the potential development of herbicide resistance in plantation weeds [12].

CONCLUSION

The application of several systemic herbicides produced different responses in controlling *Scleria sumatrensis* weeds in *Elaeis guineensis* plantations. Glyphosate treatment was identified as the most effective herbicide compared to 2,4-D dimethyl amine, metsulfuron-methyl, and penoxsulam. Glyphosate accelerated leaf wilting symptoms, produced the highest percentage of affected weeds at 95.28% at 4 weeks after application (WAA), and resulted in the lowest weed regrowth percentage of 15.17%. In contrast, dimethyl amine and metsulfuron-methyl treatments showed lower effectiveness due to higher weed regrowth after application, while penoxsulam provided a moderate weed suppression response.

Overall, the results indicated that appropriate selection of systemic herbicide active ingredients plays an important role in achieving effective and sustainable control of *Scleria sumatrensis* in oil palm plantations.

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