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THE EFFECT OF GLYPHOSATE AND PARAQUAT HERBICIDE USE ON THE MORTALITY OF BANDOTAN WEEDS (*Ageratum conyzoides*) IN OIL PALM PLANTATIONS

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Abstract

This study aimed to evaluate the effect of glyphosate and paraquat herbicides on the mortality rate of bandotan (*Ageratum conyzoides*) weeds in oil palm plantations. The study used a non-factorial Randomized Block Design (RBD) with 8 treatments and 3 replications, namely glyphosate (0.4, 0.5, 0.6 mL/L) and paraquat concentration (0.2, 0.3, 0.4 mL/L), as well as a control without herbicide. Observations were made for 15 days after application (HSA) based on visual changes in leaves and weed mortality rates. The results showed that the control treatment had a low weed mortality rate of 0.71 up to 15 HSA. All herbicide treatments significantly increased weed mortality. Paraquat showed the fastest response, where treatment P3 (0.4 mL/L) reached a mortality rate of 8.78 at 3 HSA and a maximum of 10.02 at 4-5 HSA. Meanwhile, glyphosate worked more slowly but remained effective, with the G3 treatment (0.6 mL/L) achieving maximum weed mortality (10.02) at 13-15 HSA. Increasing the dosage of both herbicides was positively correlated with accelerated weed mortality. Overall, paraquat was superior in accelerating weed mortality, while glyphosate was more effective in long-term control. However, the use of paraquat should be limited due to its potential environmental and health impacts. Therefore, glyphosate is recommended as a more sustainable alternative, provided appropriate dosage and application timing are used.

Keywords: *bandotan weeds, glyphosate, paraquat, weeds mortality, oil palm.*

INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) is an industrial crop producing cooking oil, industrial oil, and fuel (biodiesel). Furthermore, oil palm is a raw material for the soap, candle, tin foil, and cosmetics industries. The productivity of oil palm plantations generates significant profits, leading many long-abandoned forests and plantations to be converted into oil palm plantations. Oil palm is highly beneficial for the food, chemical, butter, and oil industries, making it crucial to the Indonesian economy (Lubis & Widanarko, 2011). The success of oil palm cultivation depends on the effective control of production factors, which are determined by the interactions among genetics, the environment, and the cultivation techniques used. Control of plant genetic factors is quite clear and is influenced by seed quality, genetic purity, and existing production potential. High production can be achieved by starting with nurseries to produce optimal planting material. The unique conditions of peatlands also require a sustainable approach to their management. This includes implementing agricultural practices that maintain ecosystem balance, such as proper drainage, proper fertilizer use, and effective weed control. To achieve good plant growth and production, intensive plant maintenance, such as weed control, is required (Barus, 2003).

Weeds are invasive plants that can be detrimental to human interests, so humans strive to control them. According to Manurung et al. (2019), weed control is one of the maintenance activities for oil palm plantations. The presence of weeds in oil palm plantations can reduce production due to competition for nutrients, water, sunlight, and living space. Weeds can also reduce production quality by contaminating weed parts, disturbing plants, acting as hosts for pests, disrupting water use, and increasing maintenance costs. Weed control is necessary to reduce competition between weed and main crops, as well as to support cultivation activities (Putri & Djaingsastro, 2025). In oil palm plantations, weed control is carried out using various methods, including manual, mechanical, cultural, biological, and chemical methods, as well as herbicides or a combination of these methods. Chemical control is carried out by spraying herbicides on the oil palm crop (Yaman et al., 2021). The effectiveness of herbicide use is greatly influenced by the dosage applied. Proper dosage can optimally suppress weed growth and development. However, if the dosage is too high, it not only reduces its effectiveness but also risks poisoning cultivated plants

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(Sembiring & Sebayang, 2019). Weed control using herbicides is popular, especially for large agricultural areas due to herbicides can control weeds before they become a nuisance, prevent damage to oil palm plantations, are more effective at killing perennial weeds and scrub, and increase oil palm yields (Djaingsastro et al., 2019). Herbicides are chemical substances used to inhibit or kill plant growth, including weeds. Herbicides are toxic to both weeds and other plants. The weed eradication process occurs because herbicides affect the chemical compounds in weed tissue, which can damage that tissue or disrupt important physiological systems necessary for its survival and growth. Herbicide selectivity refers to its ability to kill specific plant species in a mixed population without affecting other species (Ahdiat, 2017).

Two types of herbicides commonly used in plantations are glyphosate and paraquat. Glyphosate is a non-selective systemic herbicide that works post-emergence and effectively kills weeds down to the root system. Meanwhile, paraquat is a non-selective contact herbicide that acts quickly by destroying green plant tissue through an oxidative process when exposed to sunlight (Bayyinah et al., 2024). Both types of herbicides have their advantages, but their effectiveness is strongly influenced by dosage and application method. One of the weeds found in oil palm plantations is the bandotan (*Ageratum conyzoides L.*) weed. Bandotan weed is a nuisance because its presence has the potential to reduce the yield of the main crop and serve as a breeding ground for pests. Furthermore, this weed grows rapidly, capable of covering the area surrounding the oil palm plantation. Bandotan weed control is essential, one of which is the use of herbicides. Based on this problem, this study was conducted to assess the effect of glyphosate and paraquat herbicides on bandotan weed mortality. By identifying the optimal dosage, it is hoped that the results of this study can serve as a reference for oil palm farmers in implementing weed control appropriately, efficiently, and environmentally friendly, thereby sustainably increasing oil palm productivity.

METHOD

Research Design

This study used a non-factorial Randomized Block Design (RBD) with eight treatments and three replications. The experimental details are as follows:

- G0: No glyphosate application
- G1: Glyphosate 0.4 mL/L water
- G2: Glyphosate 0.5 mL/L water
- G3: Glyphosate 0.6 mL/L water
- P0: No paraquat application
- P1: Paraquat 0.2 mL/L water
- P2: Paraquat 0.3 mL/L water
- P3: Paraquat 0.4 mL/L water

Materials and Equipment

The materials used included glyphosate and paraquat herbicides, bandotan weeds, and clean water. The equipment used included a 500 mL hand sprayer, a measuring cup, raffia rope, bamboo, a machete, scissors, a tape measure, a hoe, and polybags.

Procedure

This study used 24 research plots measuring 40 cm x 40 cm, where each plot contained three polybags of bandotan weeds. Before being treated with herbicide, the weeds were left in the polybags for one week. The herbicide was applied once using a hand sprayer until the weeds were wet, with spraying carried out in the morning from 8:00 to 10:00 pm. Observations of weed leaf changes were carried out daily based on four categories: fresh (S), wilted (L), brown (C), and dead (M).

Statistical Analysis

The observation results were analyzed statistically using analysis of variance (ANOVA) to determine the significance of differences between treatments, followed by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Changes in Weed Leaf Color

The color change in the leaves of the bandotan weed is a key indicator that the herbicide is working. It generally starts green, then turns pale yellow or white. It then changes color again to a dry brown, eventually dying completely. This occurs because the herbicide damages the chlorophyll, causing the leaves to turn yellow and halting photosynthesis. Chlorophyll is the primary factor influencing photosynthesis. It harnesses solar energy, triggers CO_2 fixation to produce carbohydrates, and provides energy for the ecosystem as a whole. Carbohydrates produced in photosynthesis are converted into fats, proteins, nucleic acids, and other organic molecules (Djaingsastro et al., 2020). Without chlorophyll, plants cannot photosynthesize. In this study, changes in weed leaf color in repetitions 1, 2, and 3 are shown in Figure 1.

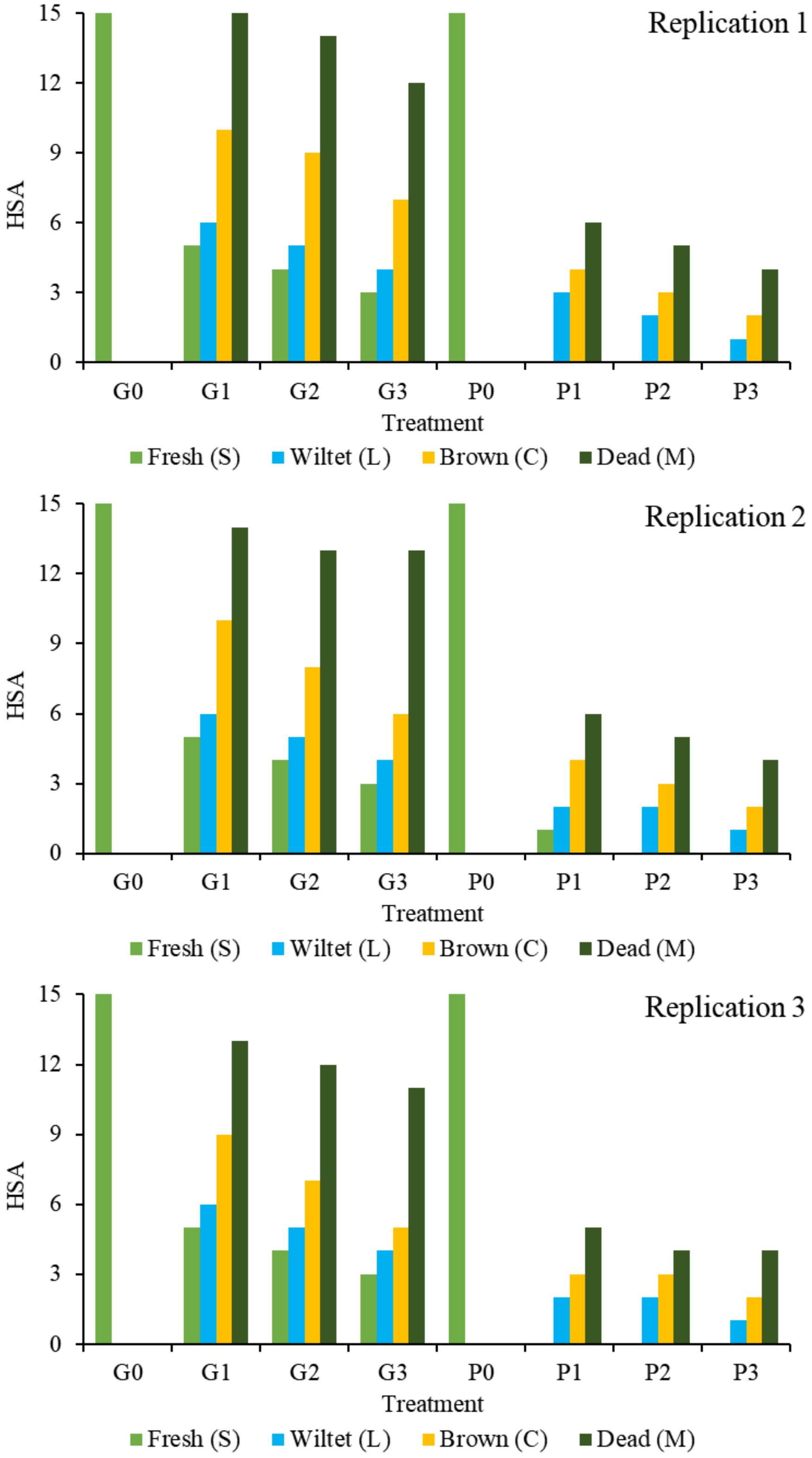

Figure 1. Changes in weed leaf color after herbicide application, 15 HSA.

In replication 1 with the G0 treatment, the weeds remained fresh (S) from day 1 to 15. In other words, there was no color change and no signs of death on the leaves. In the G1 treatment, the herbicide effect was first observed on the 6th day, when the weeds began to wilt (L), then faded to brown (C) around the 10th day, and finally died (M) on the 15th day. In other words, glyphosate worked gradually in suppressing weed death. G2 reacted faster than G1, with wilted leaves appearing from day 5, then turning brown and dying on the 14th to 15th day. Meanwhile, G3 was the most responsive in suppressing weed death, with wilted leaves appearing since day 4, then quickly turning brown and dying around the 12th to 15th day. Thus, the G3 treatment showed the strongest weed-poisoning effect. Meanwhile, in the P0 treatment, the condition of the weeds resembled that in the G0 treatment, with fresh weed leaves visible from day 1 to the 15th day. In treatment P1, weeds wilted from day one, then turned brown on day 6 and died. Finally, treatment P3 caused weed leaves to wilt, brown, and die from day one.

Observations in replication 2 also showed a weed response pattern consistent with replication 1, although there were slight differences in the rate of leaf color change. Treatment G0 had no effect, and the weeds remained healthy (S) from day 1 to day 15. This observation reinforced the control treatment's overall neutrality. Treatment G1 began working on day 6, with weeds wilting (L), then turning brown (C), and dying (M) on days 14 to 15. This sequence of changes was nearly identical to replication 1, reflecting a stable pattern. Meanwhile, treatment G2 caused weed leaves to wilt (L) on day 5, then turn brown (C) and die (M) on days 13 to 15. These findings demonstrate the increasing effectiveness of glyphosate in accelerating the toxicity process. Treatment G3 emerged as the superior treatment among its group, as indicated by earlier wilting (L) and death (M) on day 4 compared to treatments G1 and G2. Meanwhile, treatment P1 triggered a gradual change from fresh (S) to wilting (L), then to browning (C), and finally to death (M), starting on day 6. Treatment P2 had a more rapid effect than treatment P1, with weeds turning brown (C) and dying (M) visible on day 5. Finally, treatment P3 caused very rapid toxicity, with weeds wilting (L), then turning brown (C), and finally dying (M) earlier than in the other treatments.

Finally, the treatments in replication 3 showed consistent results with previous replication. Treatment G0 showed no changes, with the weeds remaining fresh (S) until day 15. Treatment G1 began causing weed leaves to wilt (L) on day 6, followed by browning (C) and death on days 13 to 15. This pattern remained consistent with the previous replication. In the G2 treatment, wilting (L) occurred earlier on day 5, then turned brown (C) and died (M) more quickly than in the G1 treatment. The G3 treatment showed the most rapid response, with wilting (L) observed from day 3 or 4 and death (M) earlier, indicating a higher level of toxicity. Meanwhile, in the P0 treatment, the weeds showed no change at all and remained healthy throughout the observation period. The P1 treatment showed a relatively rapid effect, with weeds wilting (L) early and dying (M) starting on day 5. The P2 treatment was superior compared to the P1 treatment, with weeds entering the death phase (M) within a short time. The P3 treatment was again the most effective and fastest, as the weeds were poisoned quickly and died the fastest of the other treatments.

The results showed that applying herbicides at higher concentrations tended to accelerate weed death. However, paraquat herbicides is increasingly restricted due to their negative effects on human health and the environment. In contrast, systemic herbicides like glyphosate are slower to act because they are translocated throughout the plant. They remain effective because they can destroy weeds down to the roots, preventing regrowth. This makes glyphosate a top priority for weed control in plantations, especially when combined with 2,4-D or Metsulfuron-methyl for a broader spectrum of weed control.

Weed Mortality Rate

The average mortality of bandotan weeds in 15 HSA is summarized in Table 1. Based on the results of the analysis of variance (ANOVA), the herbicide treatments of glyphosate and paraquat had a significant effect on bandotan weed mortality during most of the observation period. In general, weed mortality increased with the observation period and increasing treatment dose.

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Table 1. Average death rate of bandotan weeds after 15 HSA

Treatments	HSA															
	1		2		3		4		5		6		7		8	
G0	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a
G1	0,71	ab	1,84	ab	2,10	abc	2,39	b	3,02	b	3,44	b	3,89	b	4,34	b
G2	1,10	ab	1,61	ab	2,30	bc	2,64	bc	3,34	b	3,94	c	4,37	c	5,19	c
G3	1,64	b	2,38	bc	2,95	c	3,70	c	4,30	c	4,70	d	5,52	d	6,36	d
P0	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a
P1	2,83	c	3,59	c	5,39	d	7,54	d	9,32	d	9,85	e	10,02	e	10,02	e
P2	3,75	c	5,18	d	7,19	e	9,32	e	10,02	e	10,02	e	10,02	e	10,02	e
P3	4,53	c	7,11	e	8,78	e	10,02	e	10,02	e	10,02	e	10,02	e	10,02	e

Tabel 1. Average death rate of bandotan weeds after 15 HSA – Cont.

Treatments	HSA													
	9		10		11		12		13		14		15	
G0	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a
G1	4,56	b	5,95	ab	6,97	b	8,16	b	8,96	b	9,67	b	9,85	b
G2	6,18	c	6,86	ab	8,19	c	8,78	b	9,85	c	10,02	b	10,02	b
G3	6,99	c	8,37	bc	9,24	d	9,85	c	10,02	d	10,02	b	10,02	b
P0	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a	0,71	a
P1	10,02	d	10,02	d	10,02	d	10,02	d	10,02	d	10,02	b	10,02	b
P2	10,02	d	10,02	d	10,02	d	10,02	d	10,02	d	10,02	b	10,02	b
P3	10,02	d	10,02	d	10,02	d	10,02	d	10,02	d	10,02	b	10,02	b

Note: Numbers followed by different lowercase letters are significantly different according to Duncan's Multiple Range Test (DMRT) at the 5% level.

In the initial observation phase of 1 HSA, no significant differences among treatments were observed in bandotan weed mortality. This was evident from the relatively low, similar values, particularly in the control (G0 and P0), which remained at 0.71. This indicates that bandotan weeds have strong natural resistance, enabling them to survive and reproduce optimally without herbicide intervention. This underscores the urgency of herbicide application in weed control strategies on plantation land, particularly in tropical agricultural sectors such as oil palm plantations. Furthermore, these findings also indicate that the herbicides used, especially systemic ones, still require time to be absorbed and distributed throughout the weed network. Entering 3-5 HSA, changes between treatments became apparent. Treatment P3 showed the most rapid increase among the treatments. In this phase, weed mortality values increased significantly, with P3 reaching 8.78 at 3 HSA and 10.02 at 4-5 HSA. Meanwhile, treatments G0, G1, G2, and G3 also showed an increase, but were still below treatment P. In the period 6-10 HSA, the differences between treatments became more apparent. Treatments P3 and P2 had reached the maximum value (10.02), indicating a very fast and effective weed death response. Treatment P1 approached the maximum, while treatment G continued to increase gradually. Treatment G3 showed the best response among the G groups, but was still slower than treatment P. At 11-15 HSA, almost all treatments (except the control) had reached the maximum value of 10.02. This means that the bandotan weeds had died. Treatments P1, P2, and P3 showed high effectiveness in a relatively short time, while treatment G took longer to achieve the same results. The control (G0 and P0) showed no change (value 0.71), indicating that treatments P0 and G0 did not affect weed death. Thus, it can be concluded that increasing herbicide doses affects the speed of bandotan weed death. Treatment P3 was the most effective, providing the fastest response, followed by treatments P2 and P1.

In the group with the systemic herbicide glyphosate, there was a positive correlation between increasing dosage and the acceleration and rate of weed mortality. Treatment G1 showed the slowest response, with a gradual increase in mortality throughout the observation period. Meanwhile, treatment G2 was faster than G1, while treatment G3 provided the best performance, indicated by the largest increase in mortality at each time interval. Overall, all glyphosate doses achieved high mortality rates by the end of the observation period. Its systemic mechanism of action is absorbed through the leaves and distributed to the roots and other plant parts, allowing for complete weed eradication. However, this process requires a relatively long incubation period, so symptoms of toxicity only become apparent after several days at the beginning of the observation. In contrast, the group treated with paraquat showed a strong dose-dependent effect on the speed of the mortality response. Treatment P3 produced the fastest response, with high mortality rates from the start of the observation, reaching a maximum value earlier than the other treatments. Treatment P2 followed with high effectiveness, albeit slightly slower. Meanwhile, P1 showed the slowest results among the paraquat groups. This is due to the contact nature of paraquat, which directly damages the green tissue (chlorophyll) in the sprayed area, triggering oxygen free radicals and initiating leaf necrosis and drying within a relatively short time. However, its main weakness is paraquat's inability to reach weed roots, potentially inhibiting weed regeneration and rhizomes (underground shoots). From a contemporary plantation management perspective, the use of paraquat is increasingly restricted and even banned in many countries, including Indonesia. This is due to its high toxicity to human health, including respiratory irritation and chronic poisoning, as well as ecological impacts such as groundwater contamination and the death of non-target soil organisms. ISPO and RSPO certification regulations, through their NDPE (Non-Deforestation, No Peat, No Exploitation) policies, strictly prohibit the use of WHO Class 1A or Class 1B pesticides, including paraquat, in the interest of environmental sustainability and the safety of plantation workers. Therefore, glyphosate is recommended as a safer, more sustainable alternative, though careful application planning is required to compensate for its slower rate of action.

Low doses, such as the G1 treatment (0.4 mL/L) and the P1 treatment (0.2 mL/L), can control weeds, albeit at a slower rate. This finding has strategic implications for optimizing production costs, as dose reductions can reduce operational expenses without substantially sacrificing yields, especially in areas where time is not a priority. This approach also aligns with Integrated Pest Management (IPM) principles, which emphasize resource efficiency and minimizing chemical residues. After the bandotan weed was effectively killed, observations showed the emergence of secondary weeds, such as sedges (*Cyperus rotundus*), distinct from the original species. This phenomenon is common in tropical plantations due to the soil weed seed bank, which harbors many latent species. It is stimulated by changing environmental conditions following herbicide application, such as reduced competition from previously dominant weeds. Glyphosate is superior at preventing long-term reinvasion because it holistically eradicates the root systems of primary weeds, thereby opening up greater scope for integrated control strategies for secondary weeds like sedges, which require different approaches, such as combinations of the herbicide cycloapril or mechanical management.

CONCLUSION

This study shows that herbicide use is much more effective at killing bandotan weeds than no herbicide. In the control treatment, the weed mortality rate remained low (0.71) until the 15th day, whereas all herbicide treatments increased it to a maximum of 10.02. Paraquat works faster than glyphosate, as evidenced by the P3 treatment, which reached a mortality rate of 8.78 on the 3rd day and a peak of 10.02 on the 4th to 5th day. However, low doses can still achieve maximum mortality rates, albeit over a longer time, thus saving weed control costs. Glyphosate is superior in long-term effectiveness due to its ability to eradicate the system holistically down to the root system. On the other hand, paraquat is better suited to emergency interventions, provided they are carried out under strict supervision to avoid adverse effects on environmental sustainability and the health of workers on plantation land.

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