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Compatibility Analysis of Metolachlor and Pendimethalin for Weed Control in Arabica Coffee Plants

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Abstract

Losses caused by the presence of weeds in an agricultural business are often associated with the ability of weeds as strong competitors for plants to obtain water, nutrients, sunlight, and growing space. A mixture of metolachlor and pendimethalin herbicides is expected to control important weeds of various classes in coffee plants. The purpose of the research was to determine the effect of two herbicide mixtures at different doses on weeds in coffee plantations. This research used a 4 X 4 factorial randomized block design with 2 repetitions, resulting in 32 experimental plots. The first factor was metolachlor herbicide and the second was pendimethalin herbicide, each factor consisting of 4 levels with 0.00, 0.75, 1.75 and 2.25 kg ha-1 doses. The observed parameters consisted of (1) dominance count value, (2) percentage of controlled weeds, (3) weed coverage, (4) weed population, and (5) weed dry weight. The results showed that there was a very significant effect on the combined interaction of metolachlor and pendimethalin herbicide mixtures on the percentage of controlled weeds, percentage of weed closure at 21 and 28 DAA, and weed dry weight at 28 and 42 DAA with the best dose combination at b.a. 1.50 kg ha-1 which could increase the efficiency of weed control. Meanwhile, the percentage of controlled weeds, percentage of weed cover at 14 DAA, and weed population at 28 and 42 DAA showed very significant results independently with a dose of b.a. 2.25 kg ha-1.

Keywords: *Dose, Herbicide, Weeds, Arabica Coffee, Production*.

1. Introduction

Weeds are plants that disrupt or are detrimental to human interests, so humans try to control them. Losses caused by the presence of weeds in an agricultural business are often associated with the ability of weeds as powerful competitors to plants. The presence of weeds will cause very serious competition in gaining water, nutrients, sunlight, and a place to grow [1] [2]. Competition between weeds and plants occurs in plant production systems that is related to the limited availability of growing facilities such as water, nutrients, light, and growing space either directly or indirectly (Sembodo, 2010). Increasing coffee productivity is an effort to provide additional quality through the application of technology in accordance with proper plant management guidelines [3]. Coffee plants experience a lot of very detrimental disturbances, these disturbances are caused by weeds [4]. Yield losses related to weeds in cultivated plants are determined by the efficiency of competition between plants and weeds, weed types, soil fertility levels, varieties, allelopathy, water management, plant spacing, weed density, and planting methods [5]. Weed control with herbicides is still considered the best, as it is not only effective in suppressing weed populations, but also much more practical in its implementation [6]. Although the use of herbicides has advantages, some disadvantages are still being found so it requires further thought to anticipate the situation. Important disadvantages arising from the use of herbicides are: (1) only able to control weeds from certain groups (2) using a type of herbicide continuously will form resistant weeds, so it will be very difficult to control; (3) the emergence of weed resistance will add weed management problems. One possibility to anticipate these drawbacks is the need to combine or mix one herbicide with another. Mixing herbicides can enhance the ability to control weeds, thereby improving their effectiveness and reducing their costs [7] [8]. Mixing two or more types of herbicides has been done for a long time with the aim of obtaining synergistic or at least additive effects. If a synergistic effect is obtained, then many advantages may be obtained. Metolachlor [2 chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methyl-ethyl) acetamide] or pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzene amine] are herbicides often used in coffee plantations. Metolachlor is highly effective in controlling broadleaf weeds, sedges, and annual grasses. Metolachlor is systemic and selective [9] [10].

The active ingredient metolachlor has a mode of action that inhibits cell division. The work mechanism of metolachlor is by inhibiting chlorophyll and protein synthesis in plants. Meanwhile, pendimethalin is not only effective for controlling grass weeds but also effective for controlling broadleaf weeds with small seeds. Pendimethalin's active ingredient content is included in the dinitroaniline herbicide class, with a mode of action that inhibits the development of roots and crowns of newly germinated weeds [11]. During herbicide mixing, it is necessary to consider the biological and physical aspects of herbicides such as formulation, solubility, and ion charge. The mixture of metolachlor and pendimethalin herbicides in soybean fields had synergistic and antagonistic effects on weed populations and weed dry weight. The mixture of the two herbicides, which is at a dose of b.a 0.75 kg ha-1 and 2.25 + 0.75 kg ha-1, produces greater seed yield so that the synergistic effect is visible [12]. Mixing metolachlor and pendimethalin herbicides is expected to control important weeds of various classes in coffee plantations. To obtain synergistic effects and optimum doses in weed control and avoid toxicity effects for plants, the biological and physical aspects of metolachlor and pendimethalin herbicides need to be considered [12]. Therefore, it is necessary to study the combination of active herbicide ingredients that will be used. This research aims to determine the effect of two herbicide mixtures with various doses on weeds, determine the yield of coffee plants on population size and dry weight of weeds, and also determine the interaction properties due to mixing two herbicides [13].

2. Method

The research took place from November 2023 to February 2024 in Wih Pesam District, Bener Meriah Regency, Aceh Province at an altitude of 1269 above sea level. The tools used include measuring tape, camera, GPS, work map, bayonet, label paper, and markers, Google Earth Pro 7.3.2.5491 (64-bit), ArcGIS 10.3 software, oven, nickel cup, distilled water / clean water, tools for laboratory analysis and stationery, whereas the materials used include: metolachlor herbicide, pendimethalin herbicide, sterile distilled water wipes, Nutrient Agar (NA) media, Aluminum Foil, Tissue, plastic bags, machetes, and others [14] [15]. The experimental design used was a 4 X 4 factorial randomized block design with 2 repetitions, so there would be 32 experimental plots. The two factors are metolachlor herbicide and pendimethalin herbicide which consists of 4 levels, which are at a dose of 0.00, 0.75, 1.75 and. 2.25 kg ha-1 Parameters observed were (1) total dominance value, (2) percentage of controlled weeds, (3) weed cover, (4) weed population and (5) weed dry weight. The experimental data were analyzed by univariate variance analysis at the 5% level to determine the variation in the percentage of controlled weeds, percentage of weed cover, weed population and weed dry weight. To compare the average response to the treatment, the Least Significant Difference Test (LSD) was used at the 5% level [10].

3. Result and Discussion

3.1. Percentage of Controlled Weeds

The results of the F test in the analysis of variance showed that the interaction effect of the metolachlor and pendimethalin herbicide mixture was not significantly tested on the percentage of controlled weeds at 14 days after application (DAA), however independently the herbicide doses of metolachlor and pendimethalin were tested very significantly. Meanwhile, the interaction effect of the combination at 21 and 28 DAA was tested very significantly on the percentage of controlled weeds.

The average value of controlled weed percentage from the combined doses of metolachlor and pendimethalin herbicides individually or in a mixture after being tested with the Least Significant Difference test at the 5% level ($LSD_{0,05}$) can be seen in Tables 5, 6, and 7.

Table 1. Percentage of Controlled Weeds at 14 Days After Application in Coffee Plantation with Various Doses

Herbicide Type	Herbicide Dose b.a. kg ha^{-1}			
	0.00	0.75	1.50	2.25
	……(%)……			
Metolachlor	2.27 a	2.99 a	2.58 a	3.50 b
Pendimethalin	1.27 a	2.47 a	3.25 ab	3.89 b

Note : Numbers followed by the same letter in the same column are not significantly different according to $LSD_{0.05}$ test.
Data were transformed with √(X+0.05) before being analyzed with statistics.

Table 2. Interaction Effect of Metolachlor and Pendimethalin Herbicides with Various Dosage Combinations on the Percentage of Controlled Weeds at 21 Days After Application (DAA) in Coffee Plantations.

Metolachlor (b.a. kg ha^{-1} dose)	Pendimethalin (b.a. kg ha^{-1} dose)			
	0.00	0.75	1.50	2.25
	……(g)……			
0.00	0.71 a A	5.04 b A	7.17 c A	8.40 d A
0.75	4.20 a B	6.24 b A	7.50 b A	7.79 c A
1.50	5.52 a BC	7.10 b AB	8.60 bc AB	8.83 c A
2.25	6.74 a C	7.53 a B	8.69 ab B	9.51 b A

Note : Based on the analysis of variance, M X P tested highly significant.
Numbers marked with the same lowercase letter in the same row and the same uppercase letter in the same column are not significantly different according to $LSD_{0.05}$ test.
Data were transformed with $\sqrt{(X+0.05)}$ before being analyzed with statistics.

Table 3. Interaction Effect of Metolachlor and Pendimethalin Herbicides with Various Dosage Combinations on the Percentage of Controlled Weeds at 28 Days After Application (DAA) in Coffee Plantations.

Metolachlor (b.a. kg ha^{-1} dose)	Pendimethalin (b.a. kg ha^{-1} dose)			
	0.00	0.75	1.50	2.25
	……(g)……			
0.00	0.71 a A	5.73 b A	7.69 c A	8.07 c A
0.75	4.88 a B	7.15 ab A	7.83 ab A	8.21 b A
1.50	6.16 a BC	7.36 a A	8.61 ab B	9.01 b A
2.25	7.11 a C	7.43 a A	8.19 ab A	10.02 b B

Note : Based on the analysis of variance, M X P tested highly significant.
Numbers marked with the same lowercase letter in the same row and the same uppercase letter in the same column are not significantly different according to $LSD_{0.05}$ test.
Data were transformed with $\sqrt{(X+0.05)}$ before being analyzed with statistics.

The table above shows the percentage value of controlled weeds due to individual and combination treatments. The difference is already visible from 14 DAA to 28 DAA. The percentage of controlled weeds will continue to change consistently according to the dose of herbicide used either individually or in combination. A very interesting phenomenon to be noticed is that the single application of herbicides at a dose of b.a. 1.50 kg ha^{-1} gave a lower percentage of weed cover compared to the combined application at the same rate cumulatively (dose of b.a. 1.50 kg ha^{-1} metolachlor and dose of b.a. 1.50 kg ha^{-1} pendimethalin).

This shows that the combined mixture of the two herbicides can increase the effectiveness and also reduce the herbicide dose. Based on the above facts, the herbicide mixture has a synergistic opportunity, the assessment of the synergistic effect of a herbicide mixture is not only sufficient with qualitative data but also must be supported by quantitative data to reduce bias in the assessment.

Herbicide combinations are broad-spectrum, non-selective, and highly effective for controlling grasses, sedges, and some broad-leaved weeds. The formulation type of this herbicide is water soluble and yellow in color. Systemic herbicide toxins will enter the plant tissue through the leaves and be translocated to the roots.

Systemic herbicides work within plant tissues once the molecules have diffused into the leaf cuticle, into the xylem and phloem, and finally into the cells. The transport process of herbicide molecules follows the flow of cell mass so that the toxicity will be seen after a few days after application.

The high percentage of weed control illustrates that a large amount of herbicide is absorbed and translocated to parts of the root tissue or parts of the weed that are very sensitive to herbicides, thus disrupting the photosynthesis process and then inhibiting its growth. This is in line with the statement of Reade and Cobb (2002 as well as Pike and Hager (2004) that the dose and type of herbicide determine the herbicide activity.

The occurrence of morphological changes and death in weeds is caused by the suppression of their growth due to herbicides. The observation results are in line with the research which showed that the application of oxyfluorfen herbicide at a

dose of 1.5-2 kg b.a ha^{-1} at 15, 30, 45, and 60 HST significantly suppressed weed growth by 82.43%, 83.09%, 53.07%, and 50.56% respectively.

Research results showed that at certain doses pendimethalin herbicide can disrupt the growth of grasses and broadleaf weeds. Herbicides can inhibit the work of enzymes or physiological processes in weeds due to differences in active ingredients, mode of action, and effects on metabolic pathways.

3.2. Weed Dry Weight

The results of the F test in the analysis of variance showed that the interaction effect of the combined dose of metolachlor and pendimethalin herbicides tested very significantly at 28 and 42 DAA on weed dry weight. The mean values of weed dry weight from the combined doses of metolachlor and pendimethalin herbicides individually and in a mixture after being tested with the Least Significant Difference test at the level of 5% (LSD $_{0,05}$) can be seen in Tables 15 and 16.

Table 4. Interaction effect of metolachlor and pendimethalin herbicides with various dose combinations on weed dry weight at 21 days after application (DAA) in coffee plantations.

Metolachlor (b.a. kg ha^{-1} dose)	Pendimethalin (b.a. kg ha^{-1} dose)			
	0.00	0.75	1.50	2.25
	……(g)……			
0.00	10.74 c C	8.10 b C	7.58 a B	6.98 a B
0.75	8.80 b B	5.67 ab A	6.60 a AB	6.12 a A
1.50	7.42 c A	5.90 b B	7.11 c B	6.74 c B
2.25	3.92 a A	3.77 ab A	4.08 b A	2.50 a a

Note : Based on the analysis of variance, M X P tested highly significant.
Numbers marked with the same lowercase letter in the same row and the same uppercase letter in the same column are not significantly different according to $LSD_{0.05}$ test.
Data were transformed with √(X+0.05) before being analyzed with statistics

Table 5. Interaction effect of metolachlor and pendimethalin herbicides with various dose combinations on weed dry weight at 42 days after application (DAA) in coffee plantations

Metolachlor (b.a. kg ha^{-1} dose)	Pendimethalin (b.a. kg ha^{-1} dose)			
	0.00	0.75	1.50	2.25
	……(g)……			
0.00	11.08 c D	8.60 b B	7.18 a B	6.65 a C
0.75	8.10 b C	5.52 a A	6.41 ab B	6.12 a B
1.50	6.00 b B	6.29 b AB	6.73 c B	3.96 a A
2.25	4.78 b A	4.68 b A	4.23 b A	2.66 a a

Note : Based on the analysis of variance, M X P tested highly significant.
Numbers marked with the same lowercase letter in the same row and the same uppercase letter in the same column are not significantly different according to $LSD_{0.05}$ test.
Data were transformed with √(X+0.05) before being analyzed with statistics

The table above shows that the combined dose of metolachlor and pendimethalin with a b.a. dose of 2.25 kg ha^{-1} has been able to suppress weed growth, this is shown since 21 DAA, it is also clearly visible at 42 DAA. It can be explained that the higher the dose of metolachlor and pendimethalin herbicides applied, the lower the dry weight of the weeds. This phenomenon explains that the two types of herbicides combined show synergistic properties so that weed growth is inhibited.

Perkasa (2015) research showed that the application of metolachlor herbicide was effective in suppressing weeds with manual weeding treatment. Weeds that are difficult to control in this research are sedges, where the dry weight of weeds is high due to the presence of sedges. The lack of inhibitory effect on herbicide types of weeds was also due to their strong morphological and physiological resistance to environmental stress.

The concentration level, dose, and mode of action of herbicides affect the growth component of soybean plants. The higher the concentration and dose of herbicide, the higher the plant growth. Systemic herbicides were able to control weeds better than contact herbicides.

Higher herbicide concentrations and doses can suppress weed growth better, thus reducing the competition that occurs. Low weed competition causes the process of assimilate transport to run well as proven by the high dry weight and seed production per soybean plant. Competition between cultivated plants and weeds causes the relationship between "source" and "sink" to be disrupted, which causes low yields of soybean plants.

Pendimethalin herbicide that is absorbed by the soil can inhibit weed growth. This is indicated by a change in the colour of weed leaves which become yellowish and can cause weeds to die. This is in line with the statement of Perkasa (2015) where oxyfluorfen herbicides belong to a group with broad diphenyl ethers so that they can enter the cytoplasm, provoke the formation of peroxides and free electrons as well as destroy cell membranes instantly. The application of high doses will also affect the amount of weed dry weight as its growth and development will be inhibited.

The application of clomazone herbicide at a dose of 2.25 kg b.a ha^{-1} can reduce the types of weeds that live in soybean plants. That oxyfluorfen herbicide at a dose of 0.5 kg b.a ha^{-1} can reduce the dry weight of weeds. The effectiveness of herbicides in controlling weeds can be seen according to the value of weed dry weight. The decrease in weed dry weight will increase the percentage value of weed control in a cultivated area. The use of combined herbicides can control grass and broadleaf weeds. The results of her observations showed high symptoms of poisoning, reaching 70% of the weeds were destroyed until the end of the observation. The mixture of metolachlor and pendimethalin herbicides can suppress the growth of weeds which are herbicides that are systemic and unselective in post-growth to chlorotic as well as stopping weed growth and causing them to die

4. Conclusion

The interaction between metolachlor and pendimethalin herbicides affected the percentage of controlled weeds, the percentage of weed closure at 21 and 28 DAA, and the weed dry weight at 28 and 42 DAA with the best dose combination of b.a. 1.50 kg ha^{-1} which can increase the efficiency of weed control. Further research needs to be done on the aspect of the combination of herbicide types, as well as the class and dose of application, so that a more effective herbicide combination and synergism can be obtained.

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