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The effect of mixing two herbicides pendimethalin and sulfentrazone on characteristics of soybean yield

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Abstract. Mixing two or more herbicides is one of efforts to increase herbicide efficacy in controlling weeds, where this weed control is needed to improve soybean yield. The purpose of this study was to determine the effective dose of mixing herbicides pendimethalin and sulfentrazone and to evaluate its effect to weeds and soybean yield. This study was conducted in June to September 2019, using Randomized Completely Block Design (RCBD) with 8 treatments. Variables observed were weed dry weight, phytotoxicity, number of pods per plant, number of seeds per plant, seed weight per plant, weight of 100 seeds and dry seed yield. The results revealed that the application of mixed herbicides pendimethalin and sulfentrazone gave an effect to weed dry weight, phytotoxity, seed weight per plant, weight of 100 seeds and dry seed yield. The application of 1 kg b.a ha⁻¹ pendimethalin and 0.5 kg b.a ha⁻¹ has decreased the weed dry weight and phytotoxicity. However, it has also increased the seed weight per plant, weight of 100 seeds and dry seed yield.

1. Introduction

The presence of weeds in soybean crops can cause competition between the plant and the weeds. Not only for the nutrient, but they also compete with the crop for sunlight and water, resulting in abnormal growth of crops. Weed infestation causes severe reduction reached up to 54% [1]. [2] evaluated that the amount of yield losses caused by weeds varies between crops. This difference is attributed by plant species, weed species and the growth factors affecting both of them.

Weed control can be carried out in several methods, such as mechanical, cultural and chemical controls. These weed controls have its advantages and disadvantages. The use of chemicals in controlling weeds is known to have faster result compared to other methods. Pendimethalin and sulfentrazone are now used very extensively for controlling pre-emergence weeds in crops [3].

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Pendimethalin is a selective herbicide used to control broadleaf weeds and grassy weeds. This herbicide halts mitosis and causes spindle malfunction and disrupt cell division by inhibiting production of protein microtubule [4]. The research of [5] reported that the application of pendimethalin in certain doses were able to suppress the growth of broadleaf weeds such as *Alternanthera philoxeroides* (Alligator weed) and *Ipomoea hederacea* (Ivy-leaf morning-glory) and grassy weeds, *Brachiaria mutica* (buffalo grass), *Setaria pallide-fusca* (yellow bristle grass) and *Sorghum halepense* (Johnson grass). [6] informed that the application of pendimethalin 0.8 kg ba.ha⁻¹ has effectively controlled broadleaf weeds. However, [7] confirmed that the application of this pre-emergence herbicide alone did not increase the yield of soybean crop.

Sulfentrazone is a selective herbicide. It controls weeds by disrupting membranes and inhibiting photosynthesis in weeds [3]. This herbicide controls *Amaranthus spinosus* (spiny amaranth), *Xanthium strumarium* (rough cocklebur) and *Setaria viridis* (green foxtail). Sulfentrazone commonly used in soybean crop with dose 0.15-0.4 kg ba.ha⁻¹ depends on the texture of the soil and organic matter. Sulfentrazone absorption occurs through roots and leaves [8]. The results of research by [9] showed that sulfentrazone did not cause damage and loss of soybean plants.

To determine the effectiveness of a herbicide in controlling weeds and increasing crop yields can be done by mixing the herbicides. This is done because the application of a single herbicide, although it can control weeds well, the results are not very satisfying. According to [10], the mixing of several herbicides could obtain a broad-spectrum herbicide to control weeds. [11] has stated that a mixture of the pyroxasulfone and sulfentrazone herbicides can control weeds but it caused plant poisoning by 34% and did not reduce soybean yields. [12] found that pendimethalin 1 kg b.a ha⁻¹ applied together with imazetaphyr 70 g b.a ha⁻¹ was effective in increasing soybean yield by 68%. Based on the results mentioned above, it is necessary to do research by mixing two herbicides, pendimethalin and sulfentrazone to discover the right mixture in order to increase soybean yield.

2. Materials and methods

2.1. Place and duration

The research was conducted at Experimental Garden and at Weed Science Management Laboratory, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh from June to September 2019.

2.2. Tools and materials

Tools used in this research were handtractor, hoes, knapsack hand sprayer 15 L, syringe 3 ml and 5 ml, label stickers, oven, grain moisture meter and analytical balance. Materials used in this research were soybean seeds variety Devon 1 obtained from Balai Penelitian Tanaman Aneka Kacang dan Umbi (Balitkabi), Malang, East Java, herbicides pendimethalin and sulfentrazone, water, rooting promoter Rizogen, urea, SP-36 and KCl fertilizers, insecticides carbofuran and deltamethrin.

2.3. Data analysis

This research used Randomized Complete Block Design (RCBD) Non-Factorial with 3 replications with these following treatments:

H0 (control/without herbicides)

H1 (pendimethalin 1.5 kg ba.ha⁻¹)

H2 (sulfentrazone 1.5 kg ba.ha⁻¹)

H3 (pendimethalin 0.75 kg ba.ha⁻¹ + sulfentrazone 0.75 kg ba.ha⁻¹)

H4 (pendimethalin 1 kg ba.ha⁻¹ + sulfentrazone 1 kg ba.ha⁻¹)

H5 (pendimethalin 0.5 kg ba.ha⁻¹ + sulfentrazone 1 kg ba.ha⁻¹)

H6 (pendimethalin 1 kg ba.ha⁻¹ + sulfentrazone 0.5 kg ba.ha⁻¹)

H7 (pendimethalin 0.5 kg ba.ha⁻¹ + sulfentrazone 0.5 kg ba.ha⁻¹)

Data collected were statistically analyzed using Analysis of Variance (ANOVA) where significant differences in existed means were compared using Duncan's New Multiple Range Test (DNMRT) at 0.05 probability level.

2.4. Research methods

The land was tilled twice by using hand tractor and hoe. Independent 24 plots with size 3 m x 2.5 m were made spacing 30 cm with drainages and 100 cm for each replication. Selected soybean seeds need to be soaked into water for 15 minutes and then they were coated with rooting promoter Rizogen. Every planting hole was invested with 4 soybean seeds along with insecticide carbofuran. The space for planting the seeds were 30 cm x 30 cm. The practice of thinning plants (into 2 plants only for each hole) were done 10 days after planting to allow them plenty of growing room in order to receive all the proper growth requirements (moisture, nutrients, light, etc.) without having to compete with other seedlings.

Fertilizers used were SP36, Urea, KCl with fertilizer doses of urea 50 kg ha⁻¹, SP36 60 kg ha⁻¹ and KCl 70 kg ha⁻¹. Fertilization was carried out in stages. Urea fertilizer has been given twice, half was given during planting, by mixing the three fertilizers, while the next half was given 30 days after planting (DAP). The fertilizer was placed using ring method. Pendimethalin and sulfentrazone were applied 1 day after planting. Herbicides have been sprayed using a knapsack sprayer 15 L. Water 300 L was used to dilute the herbicide mixture. The harvesting was done 90 days after planting. When the leaves are yellow, the pods are dried and the stems are brown, soybean is ready to harvest by pulling out its roots.

2.5. Variables observed

2.5.1. Weed dry weight. Dry weight was observed at 28 days after planting. The weeds were dried in oven for 48 hours at 80°C until it has constant weight.

2.5.2. Phytotoxicity. Phytotoxicity was observed at 14, 21, 28 and 35 days after planting, done by 5 people estimating the degree of phytotoxicity in each treated plant. The percentage of phytotoxicity was obtained from the observation using rating system applied by [13].

2.5.3. Number of pods per plant. It was carried out after harvest, by calculating the average number of pods per sampled plant in the sampled plot.

2.5.4. Number of seeds per plant. This activity was done also after harvest, by calculating the seeds resulted from sampled plant in the sampled plot.

2.5.5. Seed weight per plant. The observation was made also after harvest by weighing the seeds. The seeds weighed only the seeds with moisture content 14% after being dried for 2-3 days.

2.5.6. Weight of 100 seeds. This calculation was made after weighing 100 seeds with moisture content 14%.

2.5.7 Dry seed yield. It was calculated by weighing all seeds obtained from sampled plot 120 cm x 60 cm which have been dried for 2-3 days to reach moisture content 14%.

3. Results and discussions

3.1. Weed dry weight

The results of analysis of variance indicated that the application of mixed herbicides has affected the weed dry weight compared to controls (Table 1). However, the application of these mixed herbicides had no difference compared to other application of mixed herbicides. Surprisingly, the application of sulfentrazone alone (1.5 kg ba.ha⁻¹) possessed the lowest weight of weeds. It showed that this dose was effectively controlled the weeds. This finding is in line with the result of [14] who found that the application of 1.4 kg ba. ha⁻¹ has controlled weeds reached up to 33%. [1] also confirmed that lower dry weight has described the higher percentage of weed mortality.

3.2. Phytotoxicity

The results illustrated that the mixture of herbicides was toxic to soybean plant (Table 1). The results showed that the application of pendimethalin and sulfentrazone alone exhibited higher phytotoxicity. It is thought to be due to the application of higher dose of herbicide. This result corroborates with the result of [15] and [16]. They found that younger plants could absorb greater amount of herbicides which contributed to higher and faster mortality of the plants. The research of [12] has investigated that the higher plant mortality was contributed by the application of higher dose of herbicides, resulted in high absorption and translocation by the plants through its leaves and roots. This high phytotoxicity occurs often in young plants. Similar finding was shown by [17], where he stated that young plants have better ability in absorbing nutrient, water and even herbicides, which has caused higher mortality in young plants.

Table 1. Average of weed dry weight and phytotoxicity due to application of tank mixing herbicides pendimethalin and sulfentrazone.

| Treatment (kg b.a ha ⁻¹) | Weed dry weight (g) | Phytotoxicity (%) | | |
|---|------------------------|-------------------|---------|-----------|
| | | 14 DAP | 21 DAP | 28 DAP |
| Control | 171.43 c | 3.67 a | 4.13 a | 4.67 a |
| Pendimethalin 1.5 | 32.85 b | 21 bcd | 24.20 c | 51.27 d |
| Sulfentrazone 1.5 | 1.26 a | 34.33 d | 32.07 c | 42.53 cd |
| Pendimethalin 0.75 + Sulfentrazone 0.75 | 3.22 a | 27.47 cd | 25.13 c | 35.33 bcd |
| Pendimethalin 1 + Sulfentrazone 1 | 1.77 a | 26.60 cd | 32.67 c | 46.80 d |
| Pendimethalin 0.5 + Sulfentrazone 1 | 2.98 a | 33.73 d | 28.17 c | 43.47 cd |
| Pendimethalin 1 + Sulfentrazone 0.5 | 2.44 a | 14.93 bc | 14.47 b | 28 bc |
| Pendimethalin 0.5 + Sulfentrazone 0.5 | 3.41 a | 13.55 b | 11.67 b | 22.07 b |

Mean values in the same columns followed by the same letters do not differ significantly as determined by Duncan's New Multiple Range Test ($\alpha = 0.05$)

3.3. Number of pods per plant

ANOVA results illustrated that the mixture of these two herbicides had no effect on the number of pods per plant (Table 2). The dose given in the treatments has effectively controlled the weeds, but it did not give difference for number of pods per plant. The application of tank mixing pendimethaline 1 kg b.a ha⁻¹ and sulfentrazone 0.5 kg b.a ha⁻¹ has increased the number of pods. This may be attributed by the ability of the mixture to suppress the growth of weeds, resulting in better growth of soybean where this better growth gives positive result to the number of pods.

3.4. Number of seeds per plant

The application of pendimethalin and sulfentrazone, both single and in combination also showed not significant results to number of seeds per plant (Table 2). The mixture has controlled the weeds, but it did not have effect to number of seeds per plant. The application of mixture pendimethalin 0.5 kg.ba.ha⁻¹ and sulfentrazone 1 kg ba.ha⁻¹ demonstrated an increase number of seed per plant. The results of [6] confirmed that herbicide pendimethalin has controlled broadleaf and grassy weeds, and [14] evaluated that the application of sulfentrazone effectively controlled weeds reached up to 33%.

3.5. Seed weight per plant

The results described that the application of the mixture gave significant results to the seed weight per plant (Table 2). The application of pendimethalin 1 kg ba.ha⁻¹ and sulfentrazone 0.5 kg ba.ha⁻¹

exhibited the highest weight of the seeds per plant. This has shown that this combination of herbicides controlled the weeds, where the inability the weeds to growth has allowed soybean crop to grow better, resulted in an increase of photosynthesis rate. The improvement of photosynthesis rate contributed to the upgrade of carbohydrate production which lead to an increase in seed weight. [18] stated that the application of herbicides is not only control the weeds, but it also influenced the crop growth and development.

Table 2. Average number of pods per plant, number of seeds per plant and seed weight per plant due to the application of pendimethalin and sulfentrazone.

| Treatment (kg b.a ha ⁻¹) | Number of pods per plant | Number of seeds per plant | Seed weight per plant (g) |
|---|--------------------------------|---------------------------------|---------------------------------|
| Control | 44 | 94 | 11a |
| Pendimethalin 1.5 | 55 | 113 | 17bc |
| Sulfentrazone 1.5 | 64 | 132 | 14ab |
| Pendimethalin 0.75 + Sulfentrazone 0.75 | 63 | 131 | 14ab |
| Pendimethalin 1 + Sulfentrazone 1 | 62 | 123 | 13ab |
| Pendimethalin 0.5 + Sulfentrazone 1 | 77 | 165 | 18bc |
| Pendimethalin 1 + Sulfentrazone 0.5 | 79 | 162 | 20c |
| Pendimethalin 0.5 + Sulfentrazone 0.5 | 67 | 146 | 15bc |

Mean values in the same columns followed by the same letters do not differ significantly as determined by Duncan's New Multiple Range Test ($\alpha = 0.05$)

3.6. Weight of 100 seeds

The results of analysis of variance showed that the combination of pendimethalin and sulfentrazone affected the weight of 100 seeds. The application of pendimethalin 1 kg ba.ha⁻¹ combined with sulfentrazone 0.5 kg ba.ha⁻¹ had the best result in seed weight (Table 3). This high seed weight indicated that this tank mixed treatment successfully controlled the weeds. This may allowed the crop to optimally obtain and absorb nutrient, water and sunlight.

3.7. Dry seed yield

The highest result of dry seed yield was exhibited from the application of pendimethalin 1 kg ba.ha⁻¹ mixed with sulfentrazone 0.5 kg ba.ha⁻¹, resulted from higher intensity of sunlight absorbed by the crop alone without any competition with weeds. This has led the crop to have perfect photosynthesis activity, causing an improvement of dry matter content, resulting in an increase of dry seed yield. [19] also added that there is a correlation between crop yield variable and crop yield component, which explained with formula: seed yield (Y) = seed number (SN) x weight/seed (W/S). Related to seed, [20] stated that bigger size of seed significantly increased the crop yield.

Table 3. Average weights of 100 seeds and dry seed yield of crop treated with pendimethalin and sulfentrazone.

| Treatment (kg b.a ha ⁻¹) | Weight of 100 seeds (g) | Dry seed yield (g m ⁻²) |
|---|----------------------------|--|
| Control | 12.68 ab | 256.13 a |
| Pendimethalin 1.5 | 13.66 bc | 396.33 bc |
| Sulfentrazone 1.5 | 11.47 a | 344.03 ab |
| Pendimethalin 0.75 + Sulfentrazone 0.75 | 11.64 a | 344.57 ab |
| Pendimethalin 1 + Sulfentrazone 1 | 12.41 a | 321.54 ab |
| Pendimethalin 0.5 + Sulfentrazone 1 | 11.84 a | 426.65 bc |
| Pendimethalin 1 + Sulfentrazone 0.5 | 14.51 c | 478.32 c |
| Pendimethalin 0.5 + Sulfentrazone 0.5 | 12.01 a | 347.87 ab |

Mean values in the same columns followed by the same letters do not differ significantly as determined by Duncan's New Multiple Range Test ($\alpha = 0.05$)

4. Conclusions

The herbicides pendimethalin and sulfentrazone, whether it was applied alone or in combination, it has influenced the weed dry weight, phytotoxicity, seed weight per plant, weight of 100 seeds and dry seed yield. The application of pendimethalin 1 kg ba.ha⁻¹ plus sulfentrazone 0.5 kg ba.ha⁻¹ has reduced the weed dry weight and has caused phytotoxicity. The same doses of this tank mixing herbicides also has improved the seed weight per plant, weight of 100 seeds and dry seed yield. Further research on tank mixing with different doses is important to be conducted to evaluate the effective prevention for weeds and to improve soybean yield.

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