Effect of pendimethalin and sulfentrazone on characteristics of weeds in soybean cultivation

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Abstract. Tank-mixing herbicides can increase the efficiency of weed control on soybean cultivation. The purpose of this study was to acquire the proper dose of pendimethalin and sulfentrazone both alone and in mixture to control weeds on soybean farming. It was conducted from July to September 2019 at Experimental Farm, Faculty of Agriculture, Universitas Syiah Kuala, employing non-Factorial Randomized Completely Block Design (RCBD) comprising different doses of herbicides: control, pendimethalin 1500 g a.i/ha, sulfentrazone 1500 g a.i/ha, pendimethalin 750 g a.i/ha + sulfentrazone 750 g a.i/ha, pendimethalin 1000 g a.i/ha + sulfentrazone 1000 g a.i/ha, pendimethalin 500 g a.i/ha + sulfentrazone 1000 g a.i/ha, pendimethalin 1000 g a.i/ha + sulfentrazone 500 g a.i/ha and pendimethalin 500 g a.i/ha + sulfentrazone 500 g a.i/ha. The variables observed were weed control percentage, weed species, number of weeds, and weed dry weight. The results showed that the application of pendimethalin 500 g a.i/ha together with sulfentrazone 500 g a.i/ha has increased weed control percentage and decrease weed species, number of weeds and weed dry weight.

1. Introduction

Weeds, the undesired plants, compete with crops for nutrient, water and sunlight, led to yield loss [1]. The yield loss reached up to 28-86% [2]. It is inevitable that the use of herbicides will help anticipating soybean yield loss. In this commodity, hand weeding is the usual method to reduce the weeds. However, this method requires expensive, inefficient and laborious treatments [3]. In the future, weed control in soybean will be very expensive due to an increase of labour costs and limited number of equipment and skilled labour [4]. Therefore, the application of herbicide is now recommendable in order to reduce weed control costs and the labour.

There are several herbicides applied on soybean cultivation to control weeds such as pendimethalin and sulfentrazone. Pendimethalin is a pre-emergence herbicide, used widely to control grasses and inhibits cell division by inhibiting microtubule protein production [5]. [6] explained that pendimethalin dose 500–2000 g a.i/ha is a dose to eliminate weeds on potato, tobacco, sorghum,
wheat, groundnut, soybean, sunflower, rice and sugarcane. The research of [7] showed application pendimethalin 1400 g a.i/ha has eliminated weeds and decreased the yield losses of soybean.

Sulfentrazone is a broad-spectrum herbicide applied in soybean which inhibits protoporphyrinogen oxidase, triggered the excess formation of protoporphyrinogen in the chloroplast, resulting in cell membrane inhibition, linked to cell leakage and defective cell function and cell death [8]. Sulfentrazone with dose 280-420 g a.i/ha has killed Cyperus esculentus, Amaranthus tuberculatus, Ipomoea hederacea and Abutilon theophrasti by 92-100% [9].

Mixing two herbicides can increase the efficacy of weed control and lower the cost [10]. The research of [11] shown that pendimethalin 560 g a.i/ha combined with sulfentrazone 280 g a.i/ha, a better control of grasses and broadleaves weeds was achieved. [12] confirmed that sulfentrazone 140 g a.i/ha combined with metolachlor 240 g a.i/ha increased broadleaves weeds control by 98%.

2. Materials and methods

2.1. Place and duration
This research was carried out at Experimental Farm and at Weed Management Laboratory, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh from July to October 2019.

2.2. Equipment and materials
Hand tractor, hoes, analytical balance (max 1000g) and knapsack sprayer were employed in this study and using soybean seeds var. Devon-1, herbicides pendimethalin, sulfentrazone, Rhizogen, N, P$_2$O$_5$ (Petrokimia Gresik) and K$_2$O fertilizers, insecticides klorpirifos.

2.3. Data analysis
This research used Non-Factorial Randomized Completely Block Design (RCBD) comprising 8 treatments and 3 replications, where different herbicides and different dose were investigated to evaluate its effect on soybean yield: control (A), 1500 g a.i/ha sulfentrazone (B), 1500 g a.i/ha pendimethalin (C), 750 g a.i/ha pendimethalin + 750 g a.i/ha sulfentrazone (D), 1000 g a.i/ha pendimethalin + 1000 g a.i/ha sulfentrazone (E), 1000 g a.i/ha pendimethalin + 500 g a.i/ha sulfentrazone (F) and 500 g a.i/ha + 500 g a.i/ha sulfentrazone (G). The variables observed were weed control percentage, weed species, number of weeds, and weed dry weight. ANOVA test was assigned for data analysis, where significant differences mean separated using Least Significant Difference (LSD) at probability level 0.05.

2.4. Research methods
The field was tilled using handtractor before the experiment was initiated. The 24 plots sized 4 m x 2 m were built with distance 40 cm between treatments and 150 cm between replications. Sorted seeds were soaked in the water and were coated with Bradyrhizobium japonicum and klorpirifos. Planting holes (2 cm in depth) were prepared and selected 4 seeds were planted with the distance between planting holes 40 cm x 20 cm. Plant thinning was carried out at 10 days after planting. Fertilizers N (30 kg/ha), P$_2$O$_5$ (35 kg/ha) and K$_2$O (40 kg/ha) were applied with row method at different specific time point where half doses of N, P$_2$O$_5$ and K$_2$O were applied after the seed being sowed and another half doses were at 4 weeks after planting (WAP). The herbicides were applied 1 day after planting using knapsack sprayer (15 L). Before that, the herbicides were diluted with 350 L water ha$^{-1}$ and then were applied with distance 40 cm from the soil surface. Plant watering was done regularly in the morning and evening. Insecticide klorpirifos was applied to protect the plants from pest attack.
3. Results and discussions

3.1. Weed control percentage
The ANOVA results showed that the application of herbicides gave significant effect on weed control percentage (Table 1).

| Treatment (g. a.i ha⁻¹)                  | Weed control percentage (%) |
|----------------------------------------|----------------------------|
|                                        | 2 WAP | 4 WAP | 7 WAP |
| Control                                | 0 a*  | 0 a*  | 0 a*  |
| Pendimethalin 1500                     | 39 b  | 46 b  | 19 b  |
| Sulfentrazone 1500                     | 90 c  | 85 cd | 87 c  |
| Pendimethalin 750 + sulfentrazone 750  | 85 c  | 76 c  | 70 c  |
| Pendimethalin 1000 + sulfentrazone 1000| 88 c  | 85 cd | 84 c  |
| Pendimethalin 500 + sulfentrazone 1000| 85 c  | 86 d  | 71 c  |
| Pendimethalin 1000 + sulfentrazone 500| 89 c  | 77 cd | 80 c  |
| Pendimethalin 500 + sulfentrazone 500  | 87 c  | 82 cd | 77 c  |

As assessed using Least Significant Difference (LSD) (α = 0.05), mean values in the same columns followed by the same letters do not differ significantly. WAP: Weeks After Planting.

From the results, it showed the use of sulfentrazone 1500 g a.i/ha exhibited the highest weed control percentage. However, the percentage did not differ from the use of 500 g a.i/ha pendimethalin plus 500 g a.i/ha sulfentrazone. It can be said that the application of pendimethalin 500 g a.i/ha + sulfentrazone 500 g a.i/ha has efficiently increased weed control percentage. Pendimethalin inhibits tubulin polymerization, where tubulin dimers assemble into microtubules. Microtubules comprise α-tubulin and β-tubulin, perform important several cellular functions, most noticeably, mitosis [13,14]. Microtubules form the mitotic spindle segregates the chromosomes into two new cells [15]. The study by [16] showed that pendimethalin 800 g a.i/ha effectively controlled the broadleaves weeds. Also, sulfentrazone applied in the soil will be absorbed by the weed root and will be translocated throughout the weed body, contributed to metabolism inhibition causing weed mortality. This phenomenon corroborates with the finding of [17] that sulfentrazone primarily absorbed by the weeds through its roots has caused necrotic leading to death of the weeds. [18] confirmed that tank-mixing sulfentrazone 140 g a.i/ha and pyroxasulfone 210 g a.i/ha improved control of Polanisia viscosa by 78%. [19] added that herbicide combination increased the herbicide efficacy and lower the control cost.

3.2. Weed species
The results indicated that the mixing of pendimethalin and sulfentrazone affected the weed species (Table 2). The lowest weed species demonstrated using pendimethalin 1500 g a.i ha⁻¹, but it did not significantly differ compared to the use 500 g a.i ha⁻¹ mixed with sulfentrazone 500 g a.i ha, which show similar number of species at 6 WAP (2 species, indicating that the application 500 g a.i ha⁻¹ mixed with sulfentrazone 500 g a.i/ha was more efficient).

The lower weed species has proved that dose of herbicides applied was significantly controlled the weeds. The results of [9] and [20] also revealed that the lower dose of pendimethalin and sulfentrazone increased control of grassy and broadleaf weeds, resulted in the decrease of weed species. [21] and [22] found that the application of pendimethalin combined with sulfentrazone has lessen the weed competition. As a result, the yield of soybean is increased.
### Table 2. Application of pendimethalin and sulfentrazone on weed species.

| Treatment (g. a.i/ha) | Weed species | 2 WAP | 4 WAP | 6 WAP |
|----------------------|--------------|-------|-------|-------|
| Control              |              | 6 c   | 9 c*  | 9 c   |
| Pendimethalin 1500   |              | 2 b   | 4 b   | 4 b   |
| Sulfentrazone 1500   |              | 1 a   | 2 a   | 2 a   |
| Pendimethalin 750 + Sulfentrazone 750 | | 2 b | 2 a | 2 a |
| Pendimethalin 1000 + Sulfentrazone 1000 | | 1 a | 2 a | 2 a |
| Pendimethalin 500 + Sulfentrazone 1000 | | 1 a | 2 a | 2 a |
| Pendimethalin 1000 + Sulfentrazone 500 | | 1 a | 2 a | 2 a |
| Pendimethalin 500 + Sulfentrazone 500 | | 2 b | 2 a | 2 a |

As assessed using Least Significant Difference (α = 0.05), mean values in the same columns followed by the same letters do not differ significantly. WAP: Weeks After Planting

3.3. Number of weeds
In Table 3, it showed that the lowest number of weeds has caused by the application of sulfentrazone 1500 g a.i/ha. However, it was non significantly different compared to application herbicides at the lowest doses (pendimethalin 500 g a.i/ha + sulfentrazone 500 g a.i/ha). The combination of those lower doses has efficiently suppressed the number of weeds, causing lesser chance of weed competition. Generally, lower number of weeds is attributed by abnormal seed germination caused by herbicide application. The finding of [23] claimed that the combination of metribuzin 350 g a.i/ha + pendimethalin 930 g a.i/ha gave significant control on grasses and broadleaves weeds. Weed density also determines number of weeds, where lower weed density represents lower number of weeds. This statement is in line with [24] who informed that the application of pendimethalin reduced the weed density from 260/m to 103/m. The application of herbicide has caused abnormality in weed morphology, triggered to the death of weeds and reducing the number of weeds [25]. [26] evaluated that sulfentrazone 210 g a.i/ha has managed broadleaved weeds 75-100% and grasses weeds 94%.

### Table 3. Application of pendimethalin and sulfentrazone on number of weeds.

| Treatment (g. a.i ha⁻¹) | Number of weeds | 2 WAP | 4 WAP | 7 WAP |
|-------------------------|-----------------|-------|-------|-------|
| Control                 |                 | 184 b*| 209 d*| 214 d*|
| Pendimethalin 1500      |                 | 21 a  | 72 c  | 132 c |
| Sulfentrazone 1500      |                 | 11 a  | 11 a  | 13 a  |
| Pendimethalin 750 + Sulfentrazone 750 | | 12 a | 24 b | 41 b |
| Pendimethalin 1000 + Sulfentrazone 1000 | | 13 a | 18 ab | 26 ab |
| Pendimethalin 500 + Sulfentrazone 1000 | | 11 a | 22 ab | 27 ab |
| Pendimethalin 1000 + Sulfentrazone 500 | | 19 a | 21 ab | 36 b |
| Pendimethalin 500 + Sulfentrazone 500 | | 7 a  | 18 ab | 26 ab |

As assessed using Least Significant Difference (α = 0.05), mean values in the same columns followed by the same letters do not differ significantly * = transformed data (Log x). WAP: Weeks After Planting
3.4. Weed dry weight

The results in Table 4 indicated that the application of sulfentrazone 1500 g a.i/ha possessed the lowest weed dry weight compared to other doses given. However, it has no significant result compared to the use of herbicides with lower doses.

These results indicated that the application of lower doses can efficiently eliminate the weeds. The lowest doses given were pendimethalin 500 g a.i/ha + sulfentrazone 500 g a.i/ha (Table 4). The combination of these two herbicides at the lowest dose has efficiently inhibited the weed growth, resulted from improved absorption rate and herbicide translocation, which caused lower weed dry weight. [27] explained that the application of sulfentrazone can reduce the dry weight of grasses and broadleaves weeds. It is similar with the finding of [11] where pendimethalin 500 g a.i/ha + sulfentrazone 280 g a.i/ha reduce the weed dry weight. [28] reported that tank-mixed sulfentrazone 140 g a.i/ha and pyroxasulfone 100 g a.i/ha enhanced the control of broadleaves weeds by 90%. In addition, weed dry weight plays an important role in determining weed control efficiency.

Table 4. Application of pendimethalin and sulfentrazone on weed dry weight.

| Treatment (g, a.i/ha) | 2 WAP | 4 WAP | 6 WAP |
|-----------------------|-------|-------|-------|
| Control               | 7.3b* | 171.4c** | 241.8c** |
| Pendimethalin 1500    | 1.9a  | 32.8b  | 120b  |
| Sulfentrazone 1500    | 0.8a  | 1.2a   | 3.9a  |
| Pendimethalin 750 + Sulfentrazone 750 | 0.8a | 3.2a | 27.5a |
| Pendimethalin 1000 + Sulfentrazone 1000 | 0.7a | 1.7a | 9.0a |
| Pendimethalin 500 + Sulfentrazone 1000 | 0.7a | 2.9a | 25.0a |
| Pendimethalin 1000 + Sulfentrazone 500 | 1.3a | 2.4a | 11.6a |
| Pendimethalin 500 + Sulfentrazone 500 | 0.9a | 3.4a | 14.5a |

As assessed using Least Significant Difference (α = 0.05), mean values in the same columns followed by the same letters do not differ significantly. * = transformed data (√x+0.5), ** = transformed data (log x). WAP: Weeks After Planting

4. Conclusion

The application of sulfentrazone with the highest dose (1500 g a.i ha⁻¹) did reveal the highest results on weed control percentage, number of weeds and weed dry weight. However, the results did not differ compared to application of 500 g a.i ha⁻¹ pendimethalin combined with 500 g a.i ha⁻¹ sulfentrazone. Therefore, the application of herbicides with lower doses is better and recommendable.

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