Allelopathic potential of siam weed (Chromolaena odorata L.) extract for enhancing soybean productivity

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Abstract. Many tropical invasive species have strong allelopathic effects. Chromolaena odorata is reported to have the best potential to act as bioherbicide against several weeds on crops. This research was conducted in May-September 2019 to evaluate the efficacy of C. odorata extract on soybean plant. This study employed Randomized Block Design (RBD) Factorial with two factors. The first factor was 4 different doses of C. odorata extracts: 0, 8, 16 and 24 tons ha⁻¹. The second factor was 3 different times of application: 0, 7 and 14 days after planting. Variables observed were number of pods per plant, seed weight per plant, weight of 100 seeds and yield of dry seeds. The findings indicated that the extract did have effect on seed weight per plant, weight of 100 seeds, and yield of dry seeds. The application of extract 16-24 tons ha⁻¹ has improved the seed weight per plant, weight of 100 seeds, and yield of dry seeds. There was no interaction between siam weed extract and time of application in all variables observed.

1. Introduction
The use of synthetic herbicides has been considered as the most reliable and efficient methods to control weeds. However, excessive and disproportionate use of these chemicals leave residue in the soil, causing extensive environmental contamination, acute toxicity to humans and plants and lead to herbicide-resistant weeds [1,2]. Besides, broad spectrum herbicides can be toxic to the plants and its products, to a host of other organisms including birds, fish, beneficial insects, and natural enemies temporarily or permanently [3]. Therefore, to reduce the application of chemicals and the risk of developing weed resistance, the application of bioherbicides are crucial on crops, such as on soybean crop, creating safer and healthier soybean production.

Bioherbicides consist of microorganisms such as pathogens, microbes or plant extracts utilized for weed control, which are sustainable, cost-effective and environmentally friendly [4,5]. Bioherbicides prepared from the extracts of natural sources have shown promising potential against weeds. Certain
plant species have the capacity to secrete different metabolites known as allelochemicals, such as alcohols, fatty acids, phenolics, flavonoids, terpenoids, and steroids, that inhibit the reproduction, growth, and development of adjacent vegetation, including weed species [6,7,5]. However, these plant-based herbicides also possess rapid degradation in the soil, resulting in lower efficacy compared to synthetic herbicides [6].

Siam weed (Chromolaena odorata) is a perennial shrub containing allelopathic compounds, allowing them to be used as bioherbicides. It contains some main compounds such as phenol, alkaloid, triterpenoid, tannin, flavonoid and limonene [8,9]. [10] confirmed that siam weed contains 2.56% tannin. The research of [11] showed that the application of siam weed extract inhibited weed growth rate by 3%. [12] also reported that leaf extract of siam weed suppressed seed germination of nila grass (Mimosa invisa).[13] examined that siam weed concentration 40% has deterred the growth of spiny amaranth (Amaranthus spinosus). The objective of this study was to examine the allelopathic potential of siam weed (Chromolaena odorata L.) for enhancing soybean productivity.

2. Materials and Methods
This research was conducted at Assessment Institute for Agricultural Technology (Balai Pengkajian dan Teknologi Pertanian-BPTP) Aceh and at Weed Management Laboratory, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh from May to August 2019.

2.1. Equipments and materials
The equipments used in this research were hand tractor, hoe, manual weighing scale (10 kg) and analytical balance (Max. 1000 g, d. 0.5 g). The materials used were soybean seeds var. Dega 1, obtained from Indonesian Legume and Tuber Crops Research Institute (Balai Penelitian Tanaman Aneka Kacang dan Umbi-Balitkabi) in Malang, East Java, siam weed, carbofuran, fertilizers Urea, KCl and SP36 and insecticide deltamethrin.

2.2. Data analysis
The research utilized Randomized Block Design (RBD) Factorial, comprising 2 factors, siam weed extracts (D₀=0 tons ha⁻¹, D₁=8 tons ha⁻¹, D₂=16 tons ha⁻¹, and D₃=24 tons ha⁻¹) and application time (W₁=0 DAP, W₂=7 DAP and W₃=14 DAP). ANOVA test was performed to analyze the data, where existed significant means were analyzed using Duncan New Multiple Range Test (DNMRT) at probability level 5%.

2.3. Research methods
The field was tilled twice, where in the beginning the field was tilled using hand tractor and then continued using hoe. The beds were created with size 2 m x 3 m. The distance between treatments was 25 cm and 50 cm between replications. Independent 4 selected seeds were sowed into 2-cm planting holes together with the application of carbofuran 4 granules per planting hole (distance between holes 30 cm x 30 cm). Plant thinning was performed at 10 DAP. The urea fertilizer (50 kg ha⁻¹) was applied twice, half dose at 0 DAP and the other half dose at 30 DAP, while SP₃₆ and KCl fertilizers (60 kg ha⁻¹ and 70 kg ha⁻¹) was applied once. Siam weed was obtained from Ie Seu Eum Village, Mesjid Raya District, Aceh Besar Regency. The weeds, comprising leaves and stems were cut and soaked into water 200ml for 24 hours. The weeds then were squeezed and the resulting juice was filtered to be used in the research with dose per plot: 0 kg, 4.8 kg, 9.6 kg and 14.4 kg and application time 0, 7 and 14 DAP. Soybean harvest was carried out at 85 DAP, when the leaves turn yellow and start dropping and all the pods and stems have turned brown.

2.4. Observed variables
The variables observed in this research were number of pods, seed weight per plant, weight of 100 seeds and dry seed yield.
3. Results and Discussions

3.1 Number of pods per plant
The ANOVA results revealed that the extract dose and application time both single and in interaction did not significantly increased the number of pods per plant (Table 1).

Table 1. The application of siam weed extract with different doses and times on number of pods, seed weight per plant, weight of 100 seeds and seed dry yield

| Treatment | Number of pods | Seed weight per plant (g) | Weight of 100 seeds (g) | Seed dry yield (g m⁻²) |
|-----------|----------------|---------------------------|------------------------|-----------------------|
| Extract dose (tons ha⁻¹) | | | | |
| 0 | 19.63 | 9.74a | 17.85a | 233.88a |
| 8 | 20.89 | 10.29ab | 17.55a | 246.97ab |
| 16 | 21.09 | 11.26bc | 19.40b | 270.16bc |
| 24 | 21.15 | 12.10c | 20.91c | 290.31c |
| Application time | | | | |
| 0 DAP | 21.27 | 10.82 | 18.57 | 259.57 |
| 7 DAP | 20.86 | 10.87 | 18.92 | 260.96 |
| 14 DAP | 19.93 | 12.85 | 19.30 | 260.45 |

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

From the results, it indicated that siam weed extract was insignificant on number of pods per plant (Table 1), resulted from incapability of the extract to inhibit the development of weeds grown in soybean crop. However, eventhough it was insignificant, as the dose increased, the number of pods was also increased. [14] explained that siam weed extract 30% has eliminated Indian copperleaf (Acalypha indica L.) significantly. Also, the time of application gave no positive result on the number of pods. Nevertheless, earlier application has generated an increase in pod number. This phenomenon explained that when the extract was applied directly after planting, the chance of the extract being absorbed by soil is immense, resulting in seed germination inhibition. The inhibition will allow the soybean plant to grow and develop better, exhibiting an increase on pod number [15]. [16] and [17] added that the application of bioherbicide at 7 or 14 days before planting was the best time to repel the weeds.

3.2. Seed weight per plant
The results revealed that the extract increased the seed weight per plant, while application time was non-significant on seed weight (Table 1). It displayed the ability of the extract to suppress the weed growth, causing crop to absorb more nutrient, water and sunlight, contributed to an increase of seed weight. [18] informed that siam weed extract has inhibited the growth of Mikania micrantha as the dose increased. [19] stated that weed extract is beneficial to control weeds in agricultural fields. Equal distribution of high-dose weed extracts can suppress weed development by inhibiting weed physiology development [20]. The application time did not affect the seed weight. The research of [21] confirmed that application of bioherbicide obtained from yellow nutsedge (Cyperus rotundus) at 0, 5, 10 and 15 DAP did not affect the seed germination of M. invisa and M. corchorifolia.

3.3. Weight of 100 seeds
Dose extract affected seed weight per plant, while the application time did not give significant result on the seed weight (Table 1). As a result, there was no competition between the weeds and crop, led to a seed weight improvement. The weight of 100 seeds was increased as the dose increased. [22] found that 20% concentration of siam weed deterred the weed development on tea plantation, supported by the finding of [23] that 10% concentration of siam weed inhibited the germination and development of amaranth weed. Application time was insignificant on weight of 100 seeds. This is possible due to the correlation between other variables observed such as pod number and seed weight per plant as reported by [24] that there is a correlation between variables observed.
3.4. Dry seed yield
Table 1 showed that the extract increased the dry seed yield. The application of *C. odorata* 16-24 tons ha$^{-1}$ improved the yield, where this improvement is a result from decreased weed seed germination. Allelopathic compounds from the extract have eliminated the seed growth, reducing the competition between weeds and the crop, resulting in an increase of dry seed yield [25, 26] revealed that the improvement of dry seed yield was contributed by excellent nutrient absorption, enabling the plant to have sufficient N element, where this element encouraged the seed and stem formation. [27, 28] and [29] added that high dose of *C. odorata* extract can kill the weeds, improving the dry seed yield. High yield of the dry seeds is contributed by high seed weight and the weight of 100 seeds. The weight of 100 seeds determined the photosynthate partitioning between photosynthate apparatus and photosynthate allocations, which played a pivotal role related to dry seed yield [30,31]. The seed weight per plant did not differ between treatments due to application time. However, [11] claimed that of *C. odorata* extract can kill weeds in oil palm cultivation 1-5 weeks after exposure.

4. Conclusion
Siam weed extract influenced seed weight per plant, weight of 100 seeds and dry seed yield. The application of extract dose 16-24 tons ha$^{-1}$ increased the seed weight per plant, weight of 100 seeds and dry seed yield. Application time did not affect the variables observed. Further research on bioherbicide application before planting is important to be carried out to examine its effect on weed growth, development and soybean yield.

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