Effect Spraying Volume of *Cosmos sulphureus* Cav. Flower Extract on Weed Dominance and Soybean Yield

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Abstract. Allelochemical based herbicides are environmentally friendly management alternatives. Thus, cosmos (*Cosmos sulphureus* Cav.) flower extract as a bioherbicide was investigated in soybean productions. This study aimed to determine effective spraying volume of *C. sulphureus* flower extract to manage weeds based on weed dominances and soybean yield. This research was conducted at Banguntapan Village, Bantul District, Special Region of Yogyakarta Province, Indonesia on August to November 2018. This study was set as a single factor Randomized Complete Block Design (RCBD) with three replications set as blocks. Three spraying volumes; 1000, 2000, 3000 L.ha⁻¹ and two weed management practices were used as control. Continued weed free and weeded treatments were used to determine soybean yield lost. Data were analyzed using Analysis of Variance (ANOVA), continued with Least Significant Differences (LSD) at the 0.05 probability level. Results showed weed species in soybean fields was dominated by purple nutsedge (*Cyperus rotundus* L.). The 400 g.L⁻¹ extract concentration applied at 3000 L.ha⁻¹ resulted in similar weed control and soybean yield compared to pre-emergence herbicide application and manual weeding at 1 and 3 weeks after planting (WAP). These findings showed that extract of cosmos flowers possess bioherbicidal activity against weed without having detrimental effects on the soybean plants.

1. Introduction

Soybean (*Glycine max* L. Merril) is an important crop in Indonesia due to its high consumptions and protein content [1] [2] [3]. However, soybean production in Indonesia has fluctuated among years due to plant physiology, cultivation practices, biotic and abiotic factors. In addition, water availability and competition with weeds also have significant effects toward soybean yield [4].

Crop competition with weeds hinders crop growth at various levels by competing for water, nutrition, light, CO₂, and space [5]. Yield loss in soybean due to weed competition has been reported to reach 80% [6]. Purple nutsedge (*Cyperus rotundus* L.), a noxious weed, is able to grow in unfavorable condition, reproduce rapidly by vegetative methods, secrete allelopathic compounds, and is difficult to manage both
chemically and manually; thus, causing significant yield loss [7] [8] [9] [10] [11] [12]. Purple nutsedge have been reported to decrease number and weight of 100 peas [13]. The beginning of soybean growth (0-4 weeks) is an important period for soybeans to be free from weeds [4]. Therefore, weed growth should be suppressed by using chemical or mechanical methods. However, chemical controls are harmful towards the environment and human health. Also, weeds can become resistances towards these chemicals causing weed control to become even harder in the future [14] [3]. Therefore, alternative methods which are safer for the environment, such as the use of bioherbicides, are essential.

Many wild plants are sources of potential allelochemical compounds for bioherbicides [15]. Plants in the family of Asteraceae have been reported to contain phenolic compounds, such as gallic acid, ferulic acid, and p-coumarin, which are potential compounds for bioherbicides. Examples of these plants are sunflowers (Helianthus annus L.), chickweed (Ageratum conyzoides L.) [16], marigold (Tagetes sp.) [17] [15] [18] [19] and cosmos (Cosmos sulphureus Cav.) [20]. The last example has been reported to suppress purple nutsedge growth in polybag settings at concentration of 40% (w/v) [20]. However, in field settings, many factors affect bioherbicide effectiveness, such as spraying volume. Therefore, in this study, various spraying volumes were investigated to determine an effective spraying volume to suppress weed growth, especially purple nutsedges during critical period of soybean. In addition, we observed, soybean yield to determine any phytotoxic effect towards crops.

2. Materials and Methods

2.1. Materials

Three-month-old cosmos were collected from Banguntapan Village, Bantul District, Special Region of Yogyakarta Province, Indonesia (07° 48' 17" S and 110° 24' 45" E) in December 2017. Cosmos flowers were dried to constant weight in an electric oven at 40°C for 48 hours. Dried flowers were collected, ground, threshed to powder, and stored in polythene bags. Twenty and forty g of powder were passed through a 1.5 mm mesh and transferred to a labeled bottle. One hundred ml of sterile and deionized distilled water was added to the bottle and left at a room temperature (±25-26°C). After 24 hours, the material was filtered to obtain 40% extract. Solutions were then extracted again through a cloth (<0.1 mm diameter) followed by Whatman filter paper No. 1 [20].

2.2. Methods

This study was set as a single factor Randomized Complete Block Design (RCBD) with three replications set as blocks. Concentration of cosmos flower extract used was 40% (w/v). Spraying volume tested were 1000 L.ha⁻¹ (W2), 2000 L.ha⁻¹ (W3) dan 3000 L.ha⁻¹ (W4). During this study we used several control treatments, including a manually managed at 1 week after planting (WAP) and 3 WAP, a chemical pre-emergence herbicide treatment using the active ingredient oxyfluorfen at 240 gL⁻¹ and 1000 L ha⁻¹ spraying volume treated at 5 WAP, a continued weed-free treatment (for 6 weeks) and a continued weed infested area (since week 0). The latter two treatments were used to observed weed effects.

Experimental fields were ploughed and leveled. Each treatment plot was 4 × 3 m with 0.5 m distance between plots and 1 m between blocks. Each treatment plot was replicated three times. A drainage was made on the perimeter of each plot with 40 cm width and 30 cm deep. These drainages were 25 cm from each plot and blocks. Two to three soybean seeds, Gema variety, were planted 3-4 cm deep with 40 × 10 cm spacing. After a week, only one plant was left for each hole. Manure was applied 3 weeks before planting during land preparation. Amount of manure applied was 5ton.ha⁻¹ or 6 kg for each experimental plot (12 m²). Later, 120 g of SP-36, 60 g of KCl, and 30 g of urea were applied to each experimental plot. Weeding was done according to the treatments used in this experiment. To avoid unnecessary damage from insects and diseases, each plot was treated with 12 g of Furadan at seed planting, Matador (2 mL L⁻¹ of water) and Dithane (2 mL L⁻¹ of water) were applied every week until 10 weeks. Watering was done by flooding drainages until
soil reached water capacity levels. Soybean were harvested at 95 days after plating when leaves were yellowed and 95% of peas and branches reached the color dark brown.

Vegetation analysis of weeds were done before and after application of cosmos flower extracts. Analysis was done by taking three samples from each plot using a 50 × 50 cm metal grid. Weed density was calculated by measuring number of individuals of each weed species, their dominances, and dry weight from each sample. Weed data were analyzed to obtain absolute density, absolute frequency, and absolute dominance. Data of absolute density, absolute frequency and absolute dominance of weeds were used to calculate summed dominance ratio (SDR) of each species and community coefficient (C) weed of block [21]. The formulas of SDR was (relative density + relative frequency + relative dominance)/3 and the formula of community coefficient was $C = (2W/a+b) \times 100\%$, where $W$ is the sum of two lowest quantity for each type of community; a is the sum of entire quantity on first community; and b is The sum of entire quantity on second community.

Soybean productivity was observed by yield loss, and harvest index (HI) were also observed in this study. The yield loss (%) was calculated using the formula of [22]: yield loss = (weed free yield − weedy yield / weed free yield) × 100. Harvest Index was calculated according to the following formula: Harvest index (%) = Grain yield / Biological yield × 100.

2.3. Data Analyses

Data were analyzed using Analysis of Variance (ANOVA), continued with Least Significant Differences (LSD) at the 0.05 probability level. Data were analyzed using R software.

3. Result and Discussion

3.1. Weed Composition Before Land Preparation

Vegetation analysis showed there were 12 weed species collected during this study (Table 1). Before land preparation, *Cynodon dactylon* (L.) Pers. demonstrated the highest SDR (36.02%), followed by *Euphorbia heterophylla* L., *Cyperus rotundus* L., *Richardia scabra* L. respectively 16.71% dan 16.20%. Due to no SDR value reaching >50%, it implies that no weed species were dominant in the field [23]. Broad leaf and grass type weeds were the most found types in the field (43.48% and 40.92%) while sedge types were less common 15.60%. Based on their life cycles, perennial weed species (56.77%) were more common than annual weed species (43.23%).

Table 1. Weed species SDR value (%) before land preparation

| No | Weed species                  | Weed type | Life cycle | SDR (%) |
|----|-------------------------------|-----------|------------|---------|
| 1  | *Cynodon dactylon* (L.) Pers  | grass     | perennial  | 36.02   |
| 2  | *Euphorbia heterophylla* L.   | broad Leaf| annual     | 16.71   |
| 3  | *Cyperus rotundus* L.         | sedge     | perennial  | 16.20   |
| 4  | *Richardia scabra* L.         | broad Leaf| annual     | 12.02   |
| 5  | *Cleome aspera* Koen ex Dc    | broad Leaf| annual     | 4.76    |
| 6  | *Dactylotaenium aegyptium* L. | grass     | annual     | 3.33    |
| 7  | *Gynandropsis gynandra* (L.) Briq.| broad Leaf | perennial | 3.10    |
| 8  | *Commelina diffusa*           | broad Leaf| annual     | 1.85    |
| 9  | *Eleusina indica* (L.) Gaertn.| grass     | annual     | 1.57    |
| 10 | *Pyllanthus niruri* L.        | broad Leaf| annual     | 1.54    |
| 11 | *Ipomea trilobal* L.          | broad Leaf| perennial  | 1.45    |
| 12 | *Euphorbia hirta* L.          | broad Leaf| annual     | 1.45    |
Table 2. Community coefficient (C) between blocks

| Block        | Community coefficient value (C) (%) |
|--------------|-------------------------------------|
| I and II     | 85.02                               |
| I and III    | 85.51                               |
| II and III   | 76.93                               |

Obtained SDR values were used to calculate community coefficient (C) between different locations. Weed communities are considered similar when C >75%; thus, weed management used is recommended to be similar across fields [21]. The results demonstrate that weed communities between all locations were similar based on their C values (>75%) implying this location is suitable for this experiment.

3.2. Weed Composition After Application of Cosmos Flower Extract

Changes of weed community were observed after cosmos flower extract application by comparing SDR value of each weed species from each treatment at 1 and 3 weeks after applications (WAA). (Table 3). Results from the vegetation analysis indicated changes of weed composition 1 and 3 WAA; demonstrating that at 1 WAA, less weeds occurred compared before land preparation. A number of weed species were not observed at 1 WAA, such as *Commelina diffusa*, *Eleusina indica* (L.) Gaertn, *Pyllanthus niruri* L., and *Ipomea triloba* L. However, several new species were observed at all treatments except W5 during 1 WAA, including *Melochia piramidata* L. and *Corton hirtus* L.. The new species, *Physalis peruviana* L., only occurred at W0. *Cyperus rotundus* L. was the dominant weed species during 1 WAA period. These results indicate changes in weed species occurrence due to weed management. At 3 WAA period, the number of weed species increased to 15 species, especially in treatment W0.

Table 3. Weed species SDR value (%) after application of cosmos flower extract

| No | Weed species                        | SDR values (%) |
|----|-------------------------------------|----------------|
|    |                                     | W0  | W1  | W2  | W3  | W4  | W5  |
| 1  | *Cynodon dactylon* (L.) Pers (G/P)  | 12.9| 20.0| 12.0| 19.9| 10.97axy |
|    |                                     | 0   | 7.88| 6   | 6   | 5   |
| 2  | *Euphorbia heterophylla* L. (B/A)   | 8.52| 9.12| 1   | 7   | 7   |
|    |                                     | 40.0| 49.5| 43.0| 51.9| 42.5| 66.61 |
| 3  | *Cyperus rotundus* L. (S/P)         | 1   | 1   | 2   | 5   | 2   |
|    |                                     | 10.4| 10.4| 12.8| 10.9| 9.18| 5.45 |
| 4  | *Richardia scabra* Ln (B/A)         | 5   | 6   | 4   | 7   |     |
| 5  | *Cleome aspera* Koen ex Dcm (B/A)   | 2.39| 1.12| 1.43| 1.63| 1.08|     |
|    |                                     | 12.1|     |     |     |     |     |
| 6  | *Dactylotaenium aegyptium* L. (G/A) | 7   | 2.73| 2.92| 6.45|     |     |
At this period also, changes of weed composition were observed between weed management treatments (Table 3). At W0 and application of cosmos flower extract at 1000 L ha⁻¹ spraying volume, new species occurred compared to their respective treatments at 1 WAA, including *Phyllanthus niruri*, *Eleusin Indica*, *Boreria alata* (Aubl.), and *Panicum repens*. Weed species, such as *Cleome aspera* Koen ex Dcm, and *Euphorbia hirta* L., did not occur at 3 WAA even though were observed during 1 WAA on manual weed management at 1 and 3 WAP treatment. *Boreria alata* (Aubl.) and *Panicum repens* were new species found at 3 WAA. Application of cosmos flower extract at 2000 L ha⁻¹ spraying volume also resulted in the occurrence of new species, such as *Euphorbia hirta* L., *Physalis peruviana*, *Phyllanthus niruri*, and *Eleusin Indica* L. causing an increase of weed species found compared to 1 WAA. Meanwhile, at 3000 L ha⁻¹ spraying volume, number of weed species increased from 9 to 14 weed species. The new species found in this treatment included *Euphorbia hirta* L., *Physalis peruviana*, *Phyllanthus niruri*, *Boreria alata* (Aubl.), and *Panicum repens*. Five new weed species were observed at the treatment of pre-emergence herbicide application. These species include *Cleome aspera* Koen ex Dcm, *Dactylotaenium aegyptium* L., *Gynandropsis gynandra* L., *Melochia piramidata* L., and *Panicum repens* L.
Occurrences of new weed species is believed to be caused by their seeds which were previously deep in the soil. After land preparation, seeds were then brought closer to the surface and were able to germinate due to water and light availability. At both 1 WAA and 3 WAA period, *Cyperus Rotundus* L., a sedge weed species, was the dominant weed species. Weed dominance was generally similar from before land preparation to right before harvest and showed that weeds are great competitors for crops. Meanwhile, weeds that did not occur are considered to not have a great competition with crops. Purple nutsedge dominated the field and highly competes with soybean and other weed species. Purple nutsedge is a perennial weed species belonging to the Cyperaceae family which reproduce by rhizome and possess a monocotyl root system. Purple nutsedge is able to live in unfavorable conditions, such as high salinity, low light intensity to direct sunlight, and various altitudes. Rhizomes are effective reproductive organs which are able to stay viable for a long period in soil. Weeds are able to adapt to conditions with limited light, water, nutrient, CO₂ causing good growth, an increase of density, and dry weight; thus, weeds become very competitive against crops [24].

In general, at 1 WAA, broad leaf weed species were dominant between all treatments, while grass and sedge weed species had relatively the same dominance among all treatments. At 3 WAA, all treatments possess similar dominance between sedge, grass, and broad leaf weed species based on their SDR value.

### 3.3. Weed Biomass

Result demonstrate that weed biomass from weekly weeding until 3 weeks was not significantly different compared to weed-free treatment at 1 and 3 WAA. Biomass from application of cosmos flower extract at all spraying volumes were similar to manual weeding, pre-emergence herbicide, and weed-free treatment at 1 WAA, while a 3 WAA application of cosmos flower extract at all spraying volumes were only similar to pre-emergence herbicide and continuous weed infested treatment.

| Treatment                                | 1 WAA (g) | 3 WAA (g) |
|------------------------------------------|-----------|-----------|
| Continuous weed infested                 | 3.19 a    | 13.75 a   |
| Cosmos flower extract 1000 L ha⁻¹ spraying volume | 2.14 ab   | 12.23 ab  |
| Cosmos flower extract 2000 L ha⁻¹ spraying volume | 2.01 ab   | 9.97 ab   |
| Cosmos flower extract 3000 L ha⁻¹ spraying volume | 1.51 ab   | 9.29 ab   |
| Pre-emergence herbicide                  | 1.71 ab   | 7.91 b    |
| Manual weeding 1 & 3 WAP                 | 1.14 b    | 1.55 c    |
| Weed-free                                | 0.00 b    | 0.00 c    |
| CV (%)                                   | 51.14     | 35.42     |

* Numbers followed by similar letter in the same column were not significantly different based on LSD post-hoc test (α = 5%).

### 3.4. Soybean Yield, Yield Loss and Harvest Index

Yield from application of cosmos flower extract at 3000 L ha⁻¹ spraying volume were not significantly different compared to yield from pre-emergence herbicide and manual weeding at 1 and 3 WAP (Table 5). This indicates that application of cosmos flower extract at this concentration and spraying volume is able to substitute pre-emergence herbicide with the active ingredient oxyfluorfen at 1000 L ha⁻¹ spraying volume and manual weeding at 1 and 3 WAP. The highest yield was produced by weed-free treatment as much 1.31-ton ha⁻¹ soybean.
Harvest index (HI) indicates the accumulation of plant dry weight to economically valued plant parts (usually parts that are harvested) [25]. Based on previous research soybean variety Gema possess HI of 0.26–0.44. Application of cosmos flower extract at concentration of 400 gL⁻¹ and 3000 L ha⁻¹ spraying volume resulted in HI of 0.32 which was not significantly different from HI of weed-free treatment or manual weeding at 1 and 3 WAP, respectively 0.44 and 0.37. Harvest index from various weed management methods were not significantly different between each other except from the weed-free treatment. This may be caused by the small and stable environment used in this experiment. This stability is believed to be affected by genetic characteristic from stable genotypes [26]. Previous research stated that maintaining either agronomical or breeding aspect to be constant will increase grain yield [27].

Table 5. Average productivity, yield loss, and harvest index of soybeans at various weed management method

| Treatment                        | Productivity (ton ha⁻¹) | Yield Loss (%) | Harvest Index |
|----------------------------------|-------------------------|----------------|---------------|
| Continuous weed infested         | 0.22 d*                 | 83.27 a        | 0.26 b        |
| Cosmos flower extract 1000 L ha⁻¹ spraying volume | 0.42 cd               | 67.95 ab       | 0.28 b        |
| Cosmos flower extract 2000 L ha⁻¹ spraying volume | 0.54 cd               | 58.79 abc      | 0.27 b        |
| Cosmos flower extract 3000 L ha⁻¹ spraying volume | 0.85 b                | 35.37 cd       | 0.32 ab       |
| Pre-emergence herbicide          | 0.74 bc                 | 43.52 bcd      | 0.30 b        |
| Manual weeding 1 & 3 WAP         | 1.00 ab                 | 25.97 d        | 0.37 ab       |
| Weed-free                        | 1.31 a                  | 00.00 a        | 0.44 a        |
| CV (%)                           | 31.49                   | 31.57          | 24.80         |

*Numbers followed by similar letter in the same column were not significantly different based on LSD post-hoc test

Yield loss indicates weed’s effect to agricultural systems. Yield loss equal to 0 indicates that weeds are not a hindering factor in these systems. Weed are determined as plants that grow and or not wanted due to their effects. Yield loss from application of cosmos flower extract with concentration of 400 gL⁻¹ at 3000 L ha⁻¹ of spraying volume was not significantly different compared to yield loss from pre-emergence herbicide and manual weeding at 1 and 3 WAP, respectively 35.37%, 43.52% and 25.97% (Tabel 5). This implies that application of cosmos flower extract at that concentration and spraying volume is able to substitute pre-emergence herbicide and manual weeding at 1 and 3 WAP. These yield loss values show that weeds are able to decrease soybean yield and proven by yield loss up to 83.27% at continuous weed infested treatment.

Application of cosmos flower extract at 400 gL⁻¹ and 3000 L ha⁻¹ spraying volume was able to inhibit weed growth, result in soybean production and yield loss similar to pre-emergence herbicide and manual weeding at 1 and 3 WAA.

4. Conclusion

The result showed that weed composition in soybean plantation was dominated by purple nutsedge (C. rotundus). The 400 g.L⁻¹ concentration of extract applied at 3000 L.ha⁻¹ resulted in similar weed control and soybean yield compared to the pre-emergence herbicide application and manual weeding at 1 and 3 weeks after planting (WAP). These findings show that extract of cosmos flower has potential as a bioherbicide against weed without detrimental effects on soybean plants.
5. References

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