*Original Research Article*

# ALLELOPATHIC POTENTIAL OF WILD SUNFLOWER (*Tithonia diversifolia* (Hemsl.) A.Gray) AND SORGHUM (*Sorghum bicolor* (L.) Moench) AQUEOUS EXTRACTS TO CONTROL WEEDS IN COWPEA (*Vigna unguiculata* (L.) Walp) CROPPING SYSTEM




## ABSTRACT

~~A significant annual grain legume in Sri Lanka is the cowpea. Approximately 53–60% of yield losses in cowpea cultivation are attributed to weeds. Chemical weed control (herbicide), is one of the method in weed management of cowpea. Importation of herbicide have been prohibited recently since of government policy and the nation's economic problems. As a result, it's critical to identify other herbicide alternatives. In the field experiment, effect of an aqueous extract of wild sunflower and sorghum on weed parameters of the cowpea cropping system as well as the growth and yield parameters of cowpea were investigated. This study used a field experimental layout of Randomized Complete Block Design with five treatments and four replications, conducted from September to November 2022 in the crop farm of Eastern University, Sri Lanka. T1 (aqueous extract of wild sunflower; 12 L ha$^{-1}$ ,T2 (aqueous extract of sorghum; 12 L ha$^{-1}$), T3 (combined application of both wild sunflower and sorghum aqueous extract in a 1:1 ratio; 6+6 L ha$^{-1}$), T4 (hand weeding), and T5 (unweeded check-control) were the treatments. Hand weeding was done on 21 and 42 DAS while application of aqueous extracts were done on 2, 21, and 35 DAS. Weed parameters, growth and yield parameters of cowpea were collected. Minitab 17 software. It was used for the statistical analysis, and Tukey's test was used to compare the treatment means. The study showed that various weed control techniques had a substantial (P<0.05) impact on cowpea's weed, growth, and yield measurements. When compared to the control, hand weeding was found to be more effective than the other treatments. A combined application of aqueous extracts from wild sunflower and sorghum proved to be more successful in suppressing weeds than the control following hand weeding. Also, hand weeding and the combined application of extract significantly reduced the number of weeds by 82.98% and 54.39%, respectively. Further, the hand weeding and combined application of extract significantly enhanced yield by 44.75% and 62.85% respectively in comparison with the control (unweeded check). According to the study's findings, applying a combination of wild sunflower and sorghum aqueous extract instead of hand-weeding would be a more environmentally friendly way to inhibit weed growth as well as increase the growth and yield of cowpea cultivation and enhance sustainable agriculture in Sri Lanka.~~

A significant annual grain legume in Sri Lanka is the cowpea. Approximately 53–60% of yield losses in cowpea cultivation are attributed to weeds. Chemical weed control (herbicide) is one of the methods in weed management of cowpeas. Importation of herbicides has been prohibited recently due to government policy and the nation's economic problems. As a result, it is critical to identify other herbicide alternatives. In the field experiment, the effect of an aqueous extract of wild sunflower and sorghum on the cowpea cropping system's weed parameters and cowpea growth and yield parameters were investigated. This study used a field experimental layout of Randomized Complete Block Design with five treatments and four replications, conducted from September to November 2022 in the crop farm of Eastern University, Sri

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**Keywords:** *Allelochemicals, Aqueous extract, Cowpea, Hand weeding, Sorghum and Wild sunflower.*

## 1. INTRODUCTION

The cowpea (*Vigna unguiculata* L. Walp) is an important annual grain legume crop in the Fabaceae family [1]. From 10,431.2 hectares, Sri Lanka produced 11,878.1 metric tons of cowpea [2]. In addition to providing animals with food, hay, silage, and forage, cowpeas also maintain soil fertility through green manure and cover crops [3]. Insect pests and diseases, a lack of understanding of effective cultural practices, planting at a low density, low soil fertility and weeds are some of the constraints to yield losses in cowpea [4].

The biggest biological barrier to global agricultural productivity is weeds. Weeds and crops compete against each other for water, sunlight, nutrients, and space [5]. When compared to diseases (which account for 25% of losses) and insect pests (20%), weeds represent the most significant category of agricultural risks, accounting for over 45% of economic losses in field crops [6]. Weeds decreased cowpea and other legume crop yields in Nigeria by 53–60% [7]. *Dactyloctenium aegyptium, Eleusine indica, Gnaphalium indicum, Cyperus rotundus, Echinochloa crusgalli, and Sorghum halepense* are the main weeds in cowpea fields [8].

Weed control is a type of pest management that aims to inhibit the growth of weeds, particularly noxious weeds, in order to lessen their competition with desirable flora and fauna, such as domesticated plants and livestock, and to keep nonnative species from displacing native species in natural settings. The five categories of weed control are preventive, physical, cultural, biological and chemical control [9].

Several herbicides are used in chemical weed control, applied both PRE- and POST-emergence. Herbicide application has shown to be the most workable, affordable, and efficient way to eradicate even harmful or difficult-to-reach weeds [9]. However, if a human were to consume herbicide, exposure to it might be quite dangerous and result in health problems. Furthermore, some pests might get immune to pesticides, which makes it more difficult to get rid of them. The environmental contamination caused by the chemicals used could affect plants or groundwater.

Allelopathy, the direct or indirect effect of one plant species on another by chemical substances released into the root environment, could provide a different approach to controlling the weeds [10]. Many techniques, such as combination application with lower herbicide dosages, absorption into the soil, mix cropping/intercropping, surface mulching, and aqueous extracts, can be utilized to manage weeds in the field using allelopathic potentiality [11]. Substances with an allelopathic effect are known as allelochemicals. Allelochemicals include, among other substances, alkaloids, benzoxazinones, derivatives of cinnamic acid, cyanogenic compounds, ethylene, and other stimulants of seed germination.

Wild sunflower (*Tithonia diversifolia* A. Gray) is an aggressive weed with high invasive capacity because it is known to exhibit allelopathy. Flavonoids, tannins, glycosides, terpenoids, saponins, alkaloids, and phenols are the constituents of the methanolic and water extracts of wild sunflower. Wild sunflower allelochemicals are utilized to control weeds of *Amaranthus cruentus, Cleome gynandra,* and *Tridax procumbens* [12].

The allelopathic species sorghum (*Sorghum bicolor* L. Moench) inhibits the growth of weeds such as *Phalaris minor* Retz, *Rumex dentatus* L, *Chenopodium album* L. Benzoic acid, p-hydroxy benzoic acid, vanillic acid, m-coumaric acid, p-coumaric acid, gallic acid, caffeic acid, ferulic acid, and chlorogenic acid are the allelochemicals found in *Sorghum bicolor* [13].Therefore, this present study was undertaken with the following objective to find the effect of an aqueous extract of wild sunflower and sorghum on weed parameters of the cowpea cropping system as well as the growth and yield parameters of cowpea.

## 2. MATERIALS AND METHODS

### 2.1. Experimental location

The field experiment was carried out in a crop farm at the Eastern University of Sri Lanka from September to November 2022. It is located at the latitude of 7º 48'36.64" N and longitude of 81º 35'30.76" E. which comes under the Agro-Ecological Zone of the Low Country Dry Zone ($DL_2$).

### 2.2. Experimental design

A Randomized Completely Block Design with five treatments and four replications was used to set up the field trial. In the experiment T1 (aqueous extract of wild sunflower; 12 L $ha^{-1}$, T2 (aqueous extract of sorghum; 12 L $ha^{-1}$), T3 (combined application of both wild sunflower and sorghum aqueous extract in a 1:1 ratio; 6+6 L $ha^{-1}$), T4 (hand weeding), and T5 (unweeded check-control) were the treatments. Hand weeding was done on 21 and 42 DAS while application of aqueous extracts were done on 2, 21, and 35 DAS.

### 2.3. Collection of seeds

The experiment included the cowpea cultivar of 'Waruni' variety, and the seeds were collected from the sales center of Crop farm, Eastern University, Sri Lanka.

### 2.4. Aqueous extract

#### 2.4.1. Collection of Allelopathic plants

Sorghum [*Sorghum bicolor* (L.) Moench] was collected from farmers' fields in the district of Batticaloa. Wild Sunflower [*Tithonia diversifolia* (Hemsl.) A.Gray L.] was collected from a Crop farm at Eastern University, Sri Lanka. Sorghum and Wild Sunflowers were collected after harvesting the crops in the field. All the plant samples were cleaned to remove dust and other particles. The plants of sorghum and wild sunflower were cut into small pieces and were dried in a shaded area for 7 days. The dried samples of all the two species were kept in bags and labeled

#### 2.4.2. Preparation of aqueous extracts

One kilogram of dry herbage to ten liters of water (weight/volume, or w/v) was the ratio used to generate aqueous extracts from chopped dry sorghum and wild sunflower herbage, which were soaked in water separately for 24 hours [14].

### 2.5. Agronomic practices

The land was prepared using two harrowing after one ploughing to a depth of 15-20 cm. Following cleaning the land, 20 beds of 1.125 $m^2$ and spaced 30 cm by 15 cm apart were planted with cowpea variety Waruni. For ease of maintenance, 50cm was allowed between each bed and 16 planting holes spaced 30cm by 15cm apart were constructed in each bed. A total of 16 seeds were planted in each plot. The Department of Agriculture's recommendations were followed when carrying out agronomic activities including fertilizer application, irrigation, and pest and disease control.

## 2.6. Data Collection

Weed parameters such as weed density, weed fresh weight, weed control index, weed control efficiency, growth parameters such as germination percentage, plant height, fresh weight of shoot, dry weight of shoot, fresh weight of roots, dry weight of roots and yield parameters such as total number of pods per plant and total yield were recorded.

## 2.7. Analysis of Data

Collected data were statistically analyzed using the statistical software Minitab 17, and the mean comparison within treatments was performed by Tukey's test at a 5 % significant level.

## 2.8. Calculation

$$Weed\ Control\ Index = \frac{WPC - WPT}{WPC} \times 100$$

$$Weed\ control\ efficiency = \frac{WDC - WDT}{WDC} \times 100$$

WPC = Weed population in control (unweeded) plot.

WPT= Weed population in the treated plot

WDC = Weed dry weight in the control (unweeded) plot.

WDT= Weed dry weight in treated plot.

# 3. RESULTS AND DISCUSSION

## 3.1. Weed parameters

### 3.1.1. Weed density

Table 1 showed the effect of wild sunflower and sorghum aqueous extract on weed density at 35 and 50 DAS. *Richardia scabra* L., *Cyperus rotundus* L., *Digitaria sanguinalis* L. Scop, *Phyllanthus urinaria* L., *Cleome viscosa* L., and *Mollugo cerviana* L. Ser were identified as predominant weeds during the experimental period. One unanticipated finding was that *Richardia scabra* L controlled more in aqueous extract application compared with control (unweeded check).

**Table 1. The effect of aqueous extract of wild sunflower and sorghum on weed density at 35 and 50 DAS.**

| Treatments | 35 DAS | 50 DAS |
|---|---|---|
| **Wild Sunflower extract** | $65.00 \pm 1.83^{b}$ | $117.50 \pm 1.85^{b}$ |
| **Sorghum extract** | $67.25 \pm 1.25^{b}$ | $120.75 \pm 3.90^{b}$ |
| **Wild Sunflower + Sorghum extract** | $55.00 \pm 1.08^{c}$ | $88.50 \pm 4.05^{c}$ |
| **Hand weeding** | $15.75 \pm 2.29^{d}$ | $33.00 \pm 2.16^{d}$ |
| **Control (unweeded check)** | $103.00 \pm 3.54^{a}$ | $194.00 \pm 3.39^{a}$ |
| **F-Test** | * | * |

*DAS- Days After Sowing; The value is the average of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test. at the 0.05 level of probability.*

Weed density was significantly ($P$<0.05) affected by different weed control methods when compared with the control (unweeded check) at 35 and 50 DAS. The lowest weed density was recorded in hand weeding and highest weed density was recorded in control (unweeded check). After hand weeding among the aqueous extract application, minimum weed density was recorded in the combined application of extract followed by the application of aqueous extract from wild sunflower and sorghum alone.

Hand weeding was used to achieve these results because it eliminates weeds before they become mature and start to generate seeds. Furthermore, removing weeds by hand helps to get rid of their roots, rhizomes, and other underground components like tubers and stolons. Additional aqueous extract with allelochemical properties helps to modify or interfere with pathways that generate plant hormones necessary for seed germination; they also prevent weed seed germination by altering the permeability of the cell membrane and decrease the amount of water that weed seedlings take in when exposed to allelopathic stress. Additionally, they affect the photosynthetic process, cell differentiation, and metabolite concentrations required for the weeds to develop their cellular machinery [15]. It has not been documented what happens to weed density when sorghum and wild sunflower aqueous extracts are applied together. However, the results are consistent with those of Awan et al., [14] who indicated that allelopathic crop water extracts of brassica, sunflower, and sorghum in wheat significantly reduced the density of weeds.

### 3.1.2. Weed control index (%)

Table 2 showed the effect of aqueous extracts of wild sunflower and sorghum on the weed control index at 35 and 50 DAS. The results showed that weed control index was significantly ($P$<0.05) influenced by the different weed control method when compared with control at 35 and 50 DAS. The highest weed control index was recorded in the treatment hand weeding and it was followed by combined application of wild sunflower and sorghum extract. The lowest weed control index was recorded in unweeded plot. Different weed control methods of treatments wild sunflower extract, sorghum extract, combined application of wild sunflower and sorghum aqueous extract and hand weeding increased the weed control index by 39.37%, 37.79%, 54.39% and 82.98% at 50 days after sowing compared with the control (unweeded check).

**Table 2. The effect of aqueous extract of wild sunflower and sorghum on weed control index at 35 and 50 DAS.**

| Treatments | 35 DAS | 50 DAS |
|---|---|---|
| **Wild Sunflower extract** | $36.41 \pm 3.69^{bc}$ | $33.37 \pm 1.47^{c}$ |
| **Sorghum extract** | $33.63 \pm 3.42^{c}$ | $37.79 \pm 1.08^{c}$ |
| **Wild Sunflower + Sorghum extract** | $46.36 \pm 2.54^{b}$ | $54.39 \pm 1.90^{b}$ |
| **Hand weeding** | $84.83 \pm 1.95^{a}$ | $82.98 \pm 1.17^{a}$ |
| **Control (unweeded check)** | $0.00 \pm 0.00^{d}$ | $0.00 \pm 0.00^{d}$ |
| **F-Test** | * | * |

*DAS- Days After Sowing; The value is the average of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability.*

It might be due to that a larger concentration of the allelochemicals interfered with membrane permeability, photosynthesis, respiration, protein metabolism, and plant/water relationships, which significantly reduced weed growth [15].

### 3.1.3. Weed fresh weight (g)

Table 3 described the impact of aqueous extracts of wild sunflower and sorghum on the fresh weight of weeds at 50 DAS. The results revealed that the fresh weight of weeds was significantly ($P$<0.05) influenced when compared with the control (unweeded check). The lowest weed fresh weight was recorded in hand

weeding and highest weed fresh weight was recorded in control (unweeded check). After hand weeding among the aqueous extract application, minimum weed fresh weight was recorded in the combined application of extract followed by the application of aqueous extract from wild sunflower and sorghum alone. Among the aqueous extract application sorghum extract showed the highest fresh weight of weeds than wild sunflower extract.

**Table 3. The effect of aqueous extract of wild sunflower and sorghum on the fresh weight of weeds at 50 DAS.**

| Treatments | Weed fresh weight (g) |
|---|---|
| Wild Sunflower extract | 213.02 ± 5.68 [b] |
| Sorghum extract | 215.86 ± 3.35 [b] |
| Wild Sunflower + Sorghum extract | 188.85 ± 2.24 [b] |
| Hand weeding | 30.36 ± 2.49 [c] |
| Control (unweeded check) | 573.8 ± 73.4 [a] |
| **F-Test** | * |

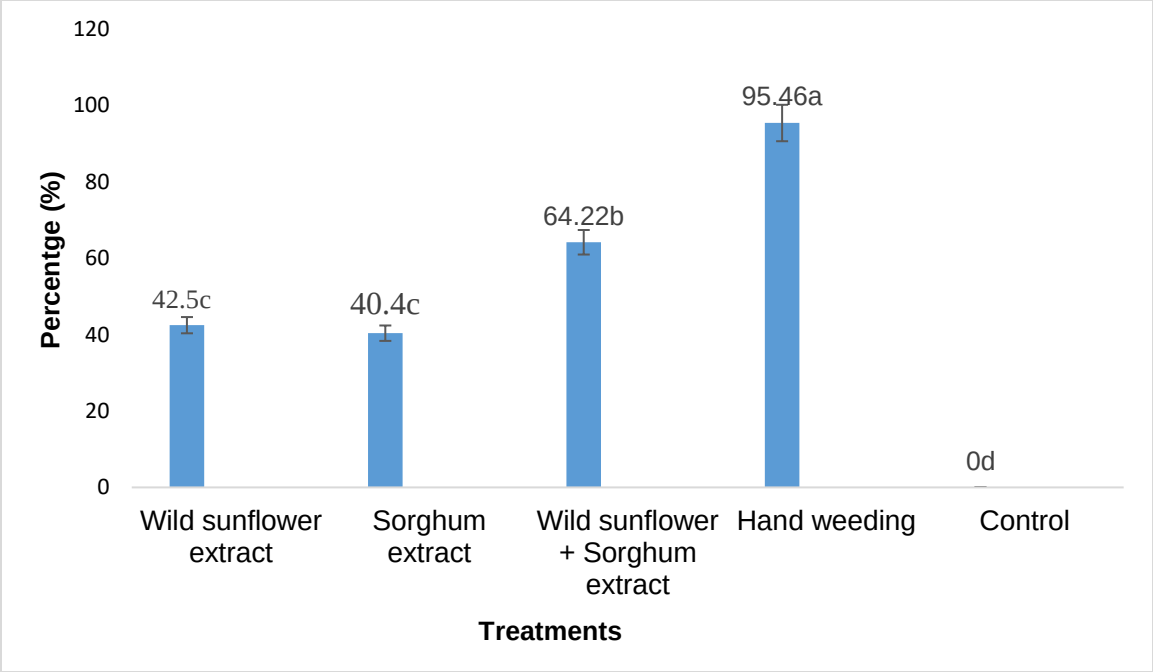
*DAS- Days After Sowing; The value is the average of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability.*

.It might be due to allelochemicals having a greater inhibitory impact in the aqueous extract of wild sunflower than sorghum. This finding is confirmed by Mubeen et al., [16] who reported more inhibitory effects of allelochemicals in the aqueous extract of sunflower than in sorghum.

### 3.1.4. Weed control efficiency (%)

Figure 1 explained the effect of aqueous extracts of wild sunflower and sorghum on weed control efficiency. There were significant differences ($P$<0.05) in the weed control efficiency when compared with the control (unweeded check) at 50 DAS. The highest weed control efficiency was reported in hand weeding than other treatments when compared with the control (unweeded check). Among the aqueous extract application, the combined application of wild sunflower and sorghum recorded more weed control efficiency when compared with control (unweeded check). The treatments of wild sunflower extract, sorghum extract, combined application of wild sunflower and sorghum aqueous extract and hand weeding enhanced the weed control efficiency by 42.58%, 40.40%, 64.22% and 95.46% compared with the control (unweeded check).

It might be due to that a larger concentration of the allelochemicals interfered with membrane permeability, photosynthesis, respiration, protein metabolism, and plant/water relationships, which significantly reduced weed growth [17]. These results reflect those of Ajayi et al., [18] who also found that hand weeding had more weed control efficiency followed by the application of wild sunflower and sorghum aqueous extract.




*Error bar denotes a standard error of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability.*

**Figure 1. The effect of aqueous extracts of wild sunflower and sorghum on weed control efficiency.**

## 3.2. Growth parameters

### 3.2.1. Germination (%)

Table 4 described the effect of the aqueous extract of wild sunflower and sorghum on the germination of cowpea. There were no significant differences ($P$>0.05) among the treatments. The germination percentages ranged from 98% to 99%.

**Table 4. The effect of an aqueous extract of wild sunflower and sorghum on the germination of cowpea.**

| Treatments | Germination (%) |
|---|---|
| Wild Sunflower extract | 99.25 ± 0.75$^{a}$ |
| Sorghum extract | 98.50 ± 0.86$^{a}$ |
| Wild Sunflower + Sorghum extract | 99.25 ± 0.75$^{a}$ |
| Hand weeding | 99.25 ± 0.75$^{a}$ |
| Control (unweeded check) | 98.50 ± 0.86$^{a}$ |
| **F-Test** | **ns** |

*The value is the average of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability*

Ajayi et al., [18] reported that 97% to 98% of germination was recorded using an aqueous extract of wild sunflower and sorghum in cowpea. This result is consistent with that of Oyerinde et al., [19] who found that the shoot extract of wild sunflower did not have an inhibitory effect on germination on maize. Similarly, Moosavi et al., [20] recorded that utilizing sorghum leaf, stem, and root extract had no significant effects on seed germination of green gram.

### 3.2.2. Plant height (cm)

Table 5 described the effect of an aqueous extract of wild sunflower and sorghum on the plant height of cowpea. Plant height was significantly varied ($P$<0.05) during 4 and 6 WAP when compared with a control (unweeded check). The higher values in plant height was recorded in the combined application of aqueous extract and the lowest plant height was recorded in a control (unweeded check) plot at 4 and 6 WAP.

**Table 5. The effect of aqueous extracts of wild sunflower and sorghum on the plant height of cowpea.**

| Treatments | 4 WAP | 6 WAP |
|---|---|---|
| Wild Sunflower extract | 40.29 ± 0.45$^{b}$ | 49.98 ± 0.65$^{b}$ |
| Sorghum extract | 40.78 ± 0.44$^{b}$ | 50.80 ± 0.45$^{b}$ |
| Wild Sunflower + Sorghum extract | 45.63 ± 0.46$^{a}$ | 54.49 ± 0.31$^{a}$ |
| Hand weeding | 44.26 ± 0.51$^{a}$ | 53.21 ± 0.29$^{a}$ |
| Control (unweeded check) | 37.27 ± 0.54$^{c}$ | 46.03 ± 0.36$^{c}$ |
| **F-Test** | * | * |

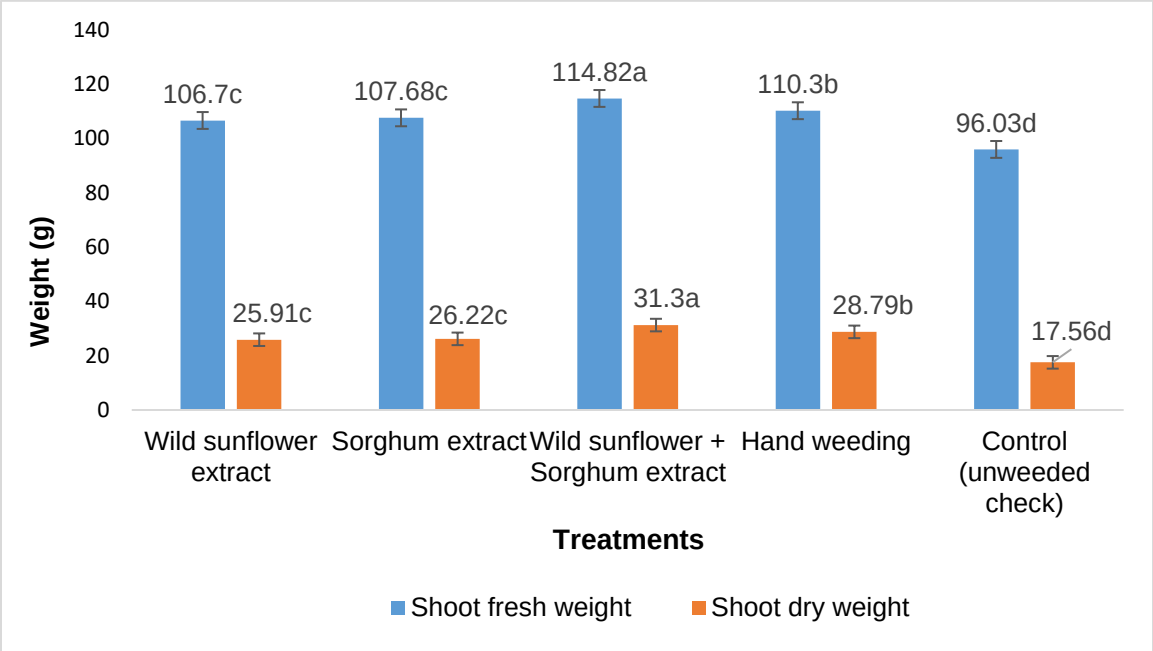
*WAP- Weeks After Planting; The value is the average of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability*

The result may have been achieved as a result of more effective weed management, which allowed the cowpea plants to make the best use of the resources at their availability, along with the nutrients present in the aqueous extract, which led to an increase in plant height. This finding is consistent with Ajayi et al., [18] who reported the allelopathic effect of wild sunflower and sorghum extract did not affect crop growth negatively.

### 3.2.3. Shoot fresh and dry weight (g)

Figure 2 described the effect of an aqueous extract of wild sunflower and sorghum on the fresh and dry weight of shoots of cowpea at 50 DAS. The fresh and dry weight of shoots was significantly ($P$<0.05) affected by the application of an aqueous extract of wild sunflower and sorghum when compared with the control (unweeded check). Among the treatments, the highest shoot and fresh weight were recorded in the combined application of extract, and the lowest shoot and fresh weight were recorded in control (unweeded check).

It might be the result of an interaction between soil microorganisms and the allelochemicals in the aqueous extracts, which converted them into nutrients and increased the amount of fresh and dry weight shoot production. The results of this study corroborate those of Oyerinde et al., [19] who found that an aqueous extract of wild sunflower greatly increased the shoot dry weight of maize, and Ajayi et al., [18] who found that an aqueous extract of sorghum and wild sunflower significantly enhanced shoot dry weight of cowpea



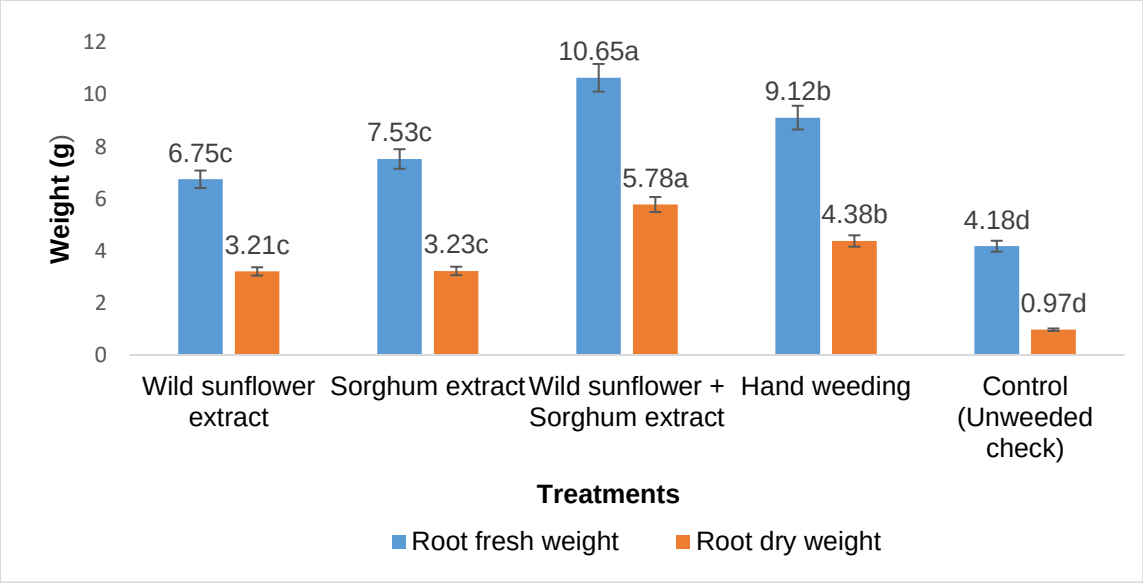

*Error bar denotes a standard error of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability.*

**Figure 2. The effect of an aqueous extract of wild sunflower and sorghum on the fresh and dry weight of shoots of cowpea at 50 DAS.**

### 3.2.4. Root fresh and dry weight (g)

Figure 3 described the effect of an aqueous extract of wild sunflower and sorghum on the fresh and dry weight of roots of cowpea at 50 DAS. The fresh and dry weight of roots was significantly ($P$<0.05) affected by the application of an aqueous extract of wild sunflower and sorghum when compared with the control (unweeded check). Among the treatments, the highest shoot and fresh weight were recorded in the combined application of extract, and the lowest shoot and fresh weight were recorded in control (unweeded check).

This result indicated higher stimulatory effects on the root fresh and dry weight than the shoot fresh and dry weight. The result might be due to the fact that roots have direct contact with the allelochemicals applied to the soil [21].




*Error bar denotes a standard error.of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability.*

**Figure 3. The effect of an aqueous extract of wild sunflower and sorghum on the fresh and dry weight of roots of cowpea at 50 DAS.**

## 3.3. Yield parameters

### 3.3.1. Pods per plant

Table 6 showed the effect of an aqueous extract of wild sunflower and sorghum on the number of pods per plant of cowpea. The number of pods per plant was significantly ($P$<0.05) affected by the aqueous extract application of wild sunflower and sorghum when compared with the control (unweeded check). The highest number of pods was recorded in the combined application of aqueous extract, and the lowest number of pods was recorded in the control (unweeded check) plot.

**Table 6. The effect of an aqueous extract of wild sunflower and sorghum on the number of pods per plant of cowpea.**

| Treatments | Pods/plant |
|---|---|
| Wild Sunflower extract | 19.12 ± 0.31$^{c}$ |
| Sorghum extract | 19.87 ± 0.42$^{c}$ |
| Wild Sunflower + Sorghum extract | 25.12 ± 0.31$^{a}$ |
| Hand weeding | 23.25 ± 0.14$^{b}$ |
| Control (unweeded check) | 15.87 ± 0.31$^{d}$ |
| **F-Test** | * |

*The value is the average of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability*

The result might be obtained due to the aqueous extract containing the allelochemicals that are responsible for controlling weeds. In addition, allelochemicals improve the mineralization of nutrients and nutrient uptake, which led to greater nutrient absorption and an increase in the number of pods per plant [18]. This finding is consistent with that of Ajayi et al., [18] who reported wild sunflower leaf extract had the highest number of pods compared with the control (unweeded check) plot.

### 3.3.2. Total yield (kg/ha)

Table 7 described the effect of an aqueous extract of wild sunflower and sorghum on the total yield. The total yield of cowpea was significantly ($P$<0.05) affected by the aqueous extracts application of wild sunflower and sorghum when compared with the control (unweeded check). The treatments of wild sunflower extract, sorghum extract, combined application of wild sunflower and sorghum aqueous extract and hand weeding increased the total yield by 20.5%, 25.3%, 62.84% and 45% compared with the control (unweeded check).

**Table 7. The effect of an aqueous extract of wild sunflower and sorghum on the total yield of cowpea.**

| Treatments | Total yield (kg/ha) |
|---|---|
| Wild Sunflower extract | 1071.6 ± 18.7$^{c}$ |
| Sorghum extract | 1114.0 ± 19.7$^{c}$ |
| Wild Sunflower + Sorghum extract | 1447.4 ± 28.$^{a}$ |
| Hand weeding | 1289.6 ± 19.3$^{b}$ |
| Control (unweeded check) | 888.8 ± 16.2$^{d}$ |
| **F-Test** | * |

*The value is the average of four replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by Tukey's test at the 0.05 level of probability*

The result might be obtained due to the aqueous extract of wild sunflower and sorghum control the weed interference of the cowpea plants during the critical period was the cause of the higher yield. According to Arif et al., [22] two foliar sprays of sorghum, sunflower, and brassica at 18 l/ha increased wheat grain yield. Ajayi et al., [18] reported wild sunflower and sorghum aqueous extract increased the yield compared with the unweeded check plot.

## 4. CONCLUSION

~~In conclusion, the effect of an aqueous extract of wild sunflower and sorghum on weed parameters of the cowpea cropping system as well as the growth and yield parameters of cowpea. Different weed control techniques had a substantial impact on cowpea's weed, growth, and yield measurements. Hand weeding was found to be more successful than the other treatments when compared to the control. After hand weeding, a combined application of aqueous extracts from wild sunflower and sorghum were found to be more effective at suppressing weeds than the control. Furthermore, hand weeding and the combined application of extract significantly suppressed the weeds by 82.98% and 54.39%, respectively. Furthermore, when compared to the control (an unweeded check), hand weeding and combined application of extract significantly improved yield by 44.75% and 62.85%, respectively. While the aqueous extract increased production and served as the primary means of controlling weeds in cowpea cropping systems, but it did not achieve the same level of weed reduction as the traditional approaches (herbicide and hand weeding). The finding will be help to add knowledge of aqueous extract of wild sunflower and sorghum could be an organic alternative to synthetic herbicides in the weed control and increase the growth and yield of cowpea cropping systems since they are less labor-intensive and have fewer negative impacts on the environment and human health.~~

In conclusion, the effect of an aqueous extract of wild sunflower and sorghum on weed parameters of the cowpea cropping system as well as the growth and yield parameters of cowpea. Different weed control techniques substantially impacted cowpea's weed, growth, and yield measurements. Hand weeding was found to be more successful than the other treatments when compared to the control. After hand weeding, combining aqueous extracts from wild sunflower and sorghum was more effective at suppressing weeds than the control. Furthermore, hand weeding and the combined application of extract significantly suppressed the weeds by 82.98% and 54.39%, respectively. Furthermore, compared to the control (an unweeded check), hand weeding and combined application of extract significantly improved yield by 44.75% and 62.85%, respectively. While the aqueous extract increased production and served as the primary means of controlling weeds in cowpea cropping systems, it did not achieve the same level of weed reduction as the traditional approaches (herbicide and hand weeding). The finding will help to add knowledge of aqueous extract of wild sunflower, and sorghum could be an organic alternative to synthetic herbicides in weed control and increase the growth and yield of cowpea cropping systems since they are less labor-intensive and have fewer negative impacts on the environment and human health.

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