

*Full Length Research Paper*

# **Allelopathy as trait of invasiveness of *Sorghum halepense* L. (Pers) on germination and establishment of weedy grass species (*Rotteboellia cochinchinensis*, *Eleusine indica* (L) and *Ipomoea purpurea*)**

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**Biology of alien plants contributes to invasiveness of both natural and agrarian ecosystems. Bio-assay experiments were set up at Bindura University of Science Education, Zimbabwe, to evaluate allelopathy as traits of invasiveness of *Sorghum halepense* L. (Pers) on germination and establishment of grass species. The results indicated that germination rate, growth rate and dry matter accumulation was highly affected by *S. halepense* extracts. Seed germination was improved by dormancy-breaking treatments, with the highest germination rate attained using a combination of sulphuric acid and potassium nitrate. Equally, the lowest germination rate was observed in seeds treated with water and a 2% sodium hypochlorite solution. The greatest seedling growth was observed in seeds treated with sulphuric acid and potassium nitrate whereas the lowest growth rate was recorded in seeds treated using sodium hypochlorite. *S. halepense* extracts affected dry matter accumulation of all grass species tested. *Rottboellia* species had the highest seed germination rate of 90%, followed by *Eleusine* 88%, and *Ipomoea* species 66% being the least. The highest germination inhibition was observed in leaves when compared to extracts from stems, roots and flowers. In pot experiments, *S. halepense* leaves affected growth and dry matter accumulation. Results showed that *S. halepense* extracts affect germination and establishment of grass species.**

**Key words:** Allelopathy, germination dynamics, grass species.

## **INTRODUCTION**

The allelopathic potential of Johnson grass [*Sorghum halepense* L. (Pers)] unlocks a fruitful area of research in weed control and nutrient cycle regulation as invasive

plants causes serious impacts on the ecosystem. They cause serious impacts on economic costs as weeds and generally affects diversity of native species, thus alter the

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broad scale of ecosystem functioning and services (Heringer et al., 2024). Recently, there has been much attention on the alterations of soil biogeochemical cycles caused by plant invasions and the broad functioning of microbial processes related to nutrients, in particular nitrogen-cycling (Rout and Callaway, 2009; Liao et al., 2008).

The most attention has been paid to processes which facilitate the establishment and persistence of species in an alien environment, including the genetic background and the subsequent expression of the genes as well as the strategy of plant life history (Rout and Callaway, 2012). Strauss et al. (2006) indicate that a number of people have recently argued that simply being related to a local population can enhance the success of invasive exotic plants (that is, the more novel the genera, the more successful an invader), while Gough et al. (2016) showed that competition in a North American herbaceous plant community was enhanced whether the plant is a native, invasive, or a naturalized species if they possessed the life history strategies of canopy dominance and clonal fragmentation. The invasive species of interest to this study, *S. halepense*, possesses both of these characteristics. Plants in the Sorghum genus are considered to be new to the North American continent, including the notorious invader, *S. halepense*, which is a cross species of *Sorghum bicolor* and *Sorghum propinquum* and is believed to have originate in the Mediterranean (Paterson et al., 1995). As is clear from this invasive weed, which now occupies both natural and agricultural ecosystems, Zimbabwe is not left out either.

The genes responsible for the modified rhizomatous growth of *S. halepense* indeed come from *S. propinquum*, even though this progenitor species has no comparative ability to produce rhizomes (Jang et al., 2006). The author goes on to state that this species is so well known for its rhizome growth that it is noteworthy. Such characteristics are frequently found in the world's most dangerous invader plants, and those that utilize the clonal growth form are able to invade, persist, and dominate notwithstanding the soil conditions (Hiero and Callaway, 2003). *S. halepense* is also known to produce robust seed to the extent of 100,000 seeds per single plant (Kagan et al., 2003). Chemically, it has been documented to possess the defensive secondary metabolite dhurrin, a cyanogenic glycoside, stored in the leaves (Nielsen and Janssen, 1999) and the allelochemical, sorgoleone, which is secreted through root hairs (Czarnota et al., 2001).

Recently, *S. halepense* was reported to contain N<sub>2</sub>-fixing bacterial endophytes in its rhizomes and monocultures of this species were found to be associated with higher concentration of some nutrients in soils that

are known to be beneficial for plant growth (Rout and Callaway, 2009). The life cycle of clonal growth and senescence of *S. halepense* is of great significance with respect to the plant's defence and allelopathy. Rhizome growth is perennial and its annual height can reach 60m per plant (Perni et al., 2009). Ramets erupt in early spring mostly from rhizome buds and contribute to dense monotypic clonal populations.

Overall, there seems to be a knowledge gap concerning *S. halepense* dealing with its chemicals associated with growth forms and the phenomenon of successful invasion and persistence in the native landscapes (Hiero and Callaway, 2003; Inderjit, 2001). This research aimed to investigate the effect of allelopathic interactions as an invasive trait of *S. halepense* through the use of aqueous extracts leached from whole plants. A lab experiment and pot trial were conducted to test the hypothesis that water-soluble leachates from Sorghum tissues can act as an allelopathic inhibitor on some dominant native grasses (*Rottboellia cochinchinensis*, *Eleusine indica* and *Ipomoea purpurea*).

## MATERIALS AND METHODS

Both field and *in vitro* (laboratory) experiments were carried out at Bindura University of Science Education which is located 6 km from Bindura town at GPS 17°18'11" South latitude and 31° East longitude. It is in Natural Region 11a which receives approximately 700-900 mm rainfall per annum and a summer average temperature range between 25 and 30°C. The site receives rains between November and December and ends in March/April. It is then followed by a cool to warm dry season from May 2016 to September 2017.

### Treatment application

Mature *S. halepense* plants growing naturally were uprooted and collected after flowering for the experiments. The plants were brought to Bindura University of Science Education Laboratory and thoroughly washed with distilled water to get rid of soil debris. The plants were air dried and immediately separated into root, leaf, stem and inflorescence. Each part of the fresh plant was cut into smaller pieces, oven dried at 60°C for 48 h and milled into fine powder using a laboratory grinding machine.

### Laboratory Bioassay evaluating *S. halepense* water extracts to control weeds

Fifty grams of each part of the ground plant material were placed in 500 ml beakers and soaked in 100 ml of distilled water for 72 h at a room temperature of 20°C. The resulting mixture was filtered through a mutton cloth which initially removes some impurities and finally through Whatman No. 40 filters paper (Ghafoor et al., 2002). The solution was kept in a refrigerator at 4°C in conical flasks covered by parafilm for further use to maintain its efficacy. Healthy uniform seeds of *R. cochinchinensis*, *I. purpurea* and *E. indica* were

**Table 1.** Treatments description.

Application	Description
1	Distilled water (control)
2	<i>Rottboellia cochinchinensis</i> in leaves extracts
3	<i>Rottboellia cochinchinensis</i> in stems extracts
4	<i>Rottboellia cochinchinensis</i> in roots extracts
5	<i>Rottboellia cochinchinensis</i> in flowers extracts
6	<i>Eleusine indica</i> in stems extracts
7	<i>Eleusine indica</i> in roots extracts
8	<i>Eleusine indica</i> in flowers extracts
9	<i>Ipomoea purpurea</i> in leaves extracts
10	<i>Ipomoea purpurea</i> in stems extracts
11	<i>Ipomoea purpurea</i> in roots extracts
12	<i>Ipomoea purpurea</i> in flowers extracts

obtained from Henderson Research Station in Mazoe.

### Experimental design and treatments

Before the germination test the seeds were surface sterilized with 0.1% sodium hypochlorite in a Petri dish<sup>®</sup> for 20 min and then rinsed several times with distilled water for 2 to 3 min to remove excess chemicals. Twenty seeds of each of the three weed species were placed in separate Petri dishes<sup>®</sup> (9.0 cm diameter) lined with filter papers to conserve moisture for the seeds. The laboratory experiment comprised of 14 treatments with four plant parts (leaf, stem, root, and flower) along with distilled water that served as a control and three weed species (*R. cochinchinensis*, *E. indica* and *I. pupurea*). The treatments were arranged in complete randomized design (CRD) with four replications, kept at room temperature on a laboratory bench with 12 h supply of fluorescent light during the night. Petri dishes<sup>®</sup> were regularly checked for moisture and in case the moisture content declined an equal amount of treatments was added to each (Table 1).

### Data collection

#### Germination percentage

After 7 days the emerged seeds were physically counted and germination percentage was calculated using the formula:

$$\text{Germination \%} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds planted}} \times 100$$

#### Seedling growth rate

In the bioassay test the plumule height and radicle length were recorded on the 8th day after planting, 10th day after planting, 12th day after planting and 14th day after planting using a string and a ruler.

#### Dry matter accumulation

At harvesting, the dry matter of the weeds was recorded. The weed

seedlings were weighed, oven dried to a constant and reweighed several times until a constant weight was achieved. Dry matter accumulation was calculated by weighing fresh weight of the weed species (initial weight) and oven dry the weeds and re-weigh to get the dry weight (final weight) and then calculated using the formula:

$$\text{Dry matter accumulation} = \frac{\text{Fresh weight}}{\text{Dry weight}} \times 100\%$$

### Data analysis

Data were captured in Microsoft Excel Spread sheets and the level of significance between means was computed by ANOVA (F-test) using the Genstat Discovery Edition 14 computer software package. The comparison of treatment means was done using Least Square Difference (LSD) at 5% level of significance.

## RESULTS

### Effects of aqueous extracts of *S. halepense* on germination of three weed species

Analysis of variance showed that there was a significant difference ( $p < 0.05$ ) in germination of the three grass species after application of the treatments. The control showed the highest germination percentage amongst all the treatments. Highest inhibition was observed from leaf extracts which seriously inhibited germination of all the test crops. The impact of *S. halepense* in reducing germination ensures that the habitat is clear of other weed species and hence in most cases *S. halepense* is found where it is a sole occupier of the habitat together with a few other tolerant species. Root and leaf extracts has the greatest inhibition on germination of *I. purpurea* with 23 and 20% germination respectively, and to a lesser extent *E. indica*. There was no significant difference ( $p < 0.05$ ) in germination of *R. cochinchinensis* after treated with control and flower extracts. Very low

germination was observed from all the treatments subjected to leaf aqueous extracts.

### **Effect of *S. halepense* root, leaf, stem and flower extracts on the seedling growth rate of three weed species**

Results prove that aqueous extracts of *S. halepense* negatively affect plumule growth of all weed species. There was a significant difference ( $p < 0.05$ ) in the plumule lengths amongst all the treatments. The control shows the-greatest-plumule-growth, there was a slight growth of the plumule amongst all the treatments. *I. purpurea* and *R. cochinchinensis* shows the greatest growth from treatment with the flower extract; whilst on stem extracts *I. purpurea* shows the greatest growth rate. There was no significant difference ( $p > 0.05$ ) in the plumule length of *E. indica* grass from treatment with flower or root extracts. *E. indica* plumule growth was negatively affected by the aqueous extracts of *S. halepense*. Amongst the three weed species *I. purpurea* was not highly affected by root and flower extracts. *E. indica* was negatively affected by *S. halepense* leaf, stem and root extracts. *S. halepense* proves to have a normative effect on the length of plumules in all three test weeds (Figure 2).

### **Interaction effects of *S. halepense* plant parts and weed species on radicle length (cm)**

There was a significant difference ( $p < 0.05$ ) between the control and aqueous extracts from plant parts on the length of the radicle of all the weed species. The negative effect of *S. halepense* extracts on the radicle growth of weed species was confirmed. The control shows the longest radicle length in comparison to the test crops. Root extracts showed the greatest inhibitory effects on the growth of the radicle of *E. indica* (Figure 3). There was no-significant-difference- ( $p > 0.05$ ) between extracts from root and leaf plant parts on the radicle growth of *E. indica* and *R. cochinchinensis*. Growth of radicle was gradually diminished in all aqueous extracts of *S. halepense*. The main allelopathic effects are delayed radicle growth and this leads results in physiological effects which will retard growth and dry matter accumulation in seedlings (Table 2).

### **Effects of *S. halepense* root, leaf, stem and flower extracts on dry-matter-accumulation of three weed-species**

There was a significant difference ( $p < 0.05$ ) between the

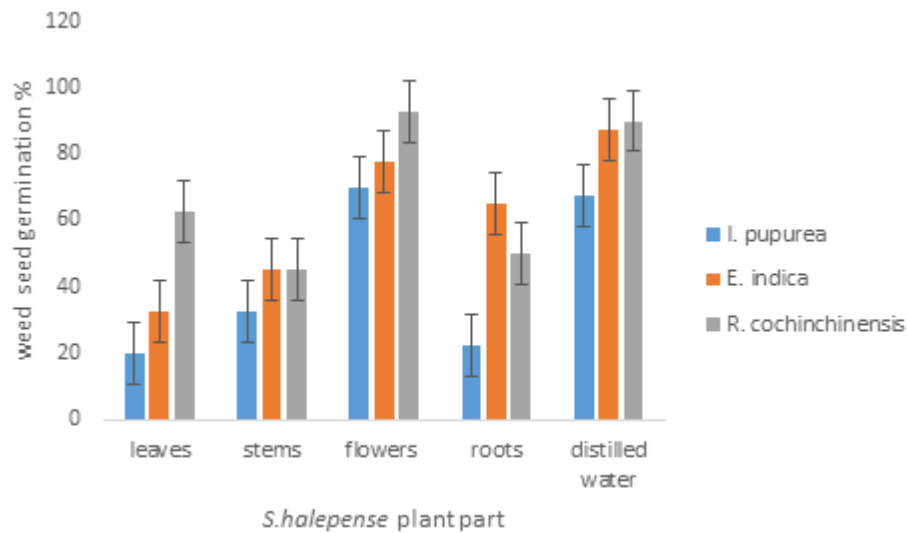
control and all other treatments on dry matter accumulation of the three weed species. There is no significant difference in dry-matter-accumulation between *E. indica* and *I. Purpurea* after treatment with root extracts. A complete leaf biomass inhibitory effect was observed in root extracts on *R. cochinchinensis*. The inhibitory effects of dry matter accumulation among plant parts were mostly found on stem extracts.

## **DISCUSSION**

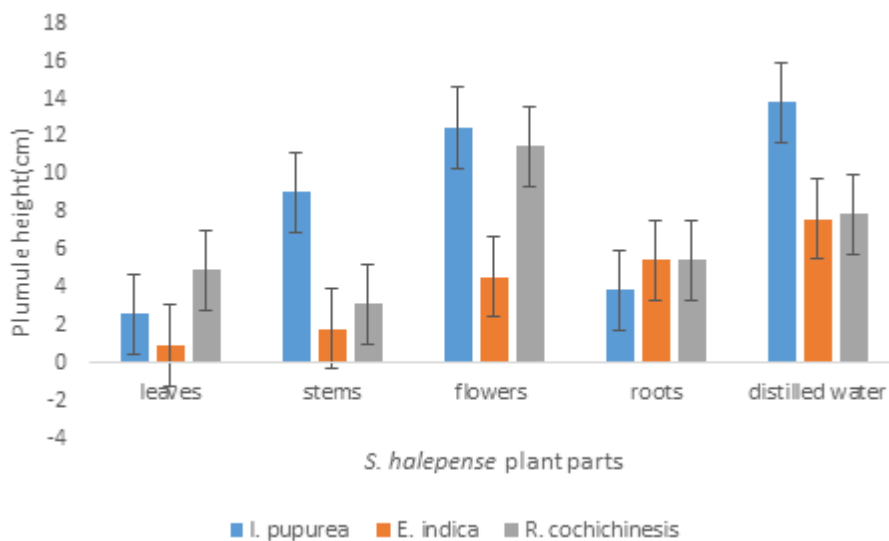
The results show that Johnson grass (*S. halepense*) possesses some allelochemicals that affect germination of three grass species. *S. halepense* leaves extract displayed the highest inhibition effects on the germination of *R. cochinchinensis*, *E. indica* and *I. purpurea* (Figure 1). *I. purpurea* was highly affected by leaf extracts followed by root extracts. Comparable results were also found by Shackleton et al. (2019) who reported that *T. diversifolia* has allelochemicals which affect morphological processes such as germination in many plants. Musyimi et al. (2015) noted that allelochemicals have an inhibitory effect on water imbibition which as a result slows down the hydrolysis of the food components inside the seeds. Moreover, the allelochemical complex of the Johnson grass parts could be the ones responsible for inhibiting the peroxidase alpha-amylase and acid phosphatases which aid in the dissolution of starch in germinating seeds. *S. halepense* inhibited both germination and seedling growth of the three grass species. The negative effects of *S. halepense* on germination three weed species are presented in Figure 1.

The aqueous extracts of *S. halepense* showed several seedling growth patterns depending on the parts applied to the bioassay test species. The study revealed that the allelopathic effect depended on the treatment containing the plant part extract and the weed species. The effects of *S. halepense* in inhibiting germination confirm that it dominates other species and henceforth in many instances the weed was found where it was the only occupant of the habitation. The study stipulates that all the aqueous extracts from the parts of *S. halepense* caused inhibit germination of the three weed seeds.

Seedling growth of all the crops used for the experiment was negatively affected by the aqueous extracts of *S. halepense*. *I. pupurea* grass shows to be the most affected crop amongst all the three weeds this implies that animal fodder become scarcity in *S. halepense* infested areas. This scenario has a normative impact on both leather and meat industry (Musabayana, 2024). The results show that flower extracts had no effects on growth of seedlings and it fails to inhibit both



**Figure 1.** Interaction effect of *S. halepense* plant parts and weed species on germination percentage.

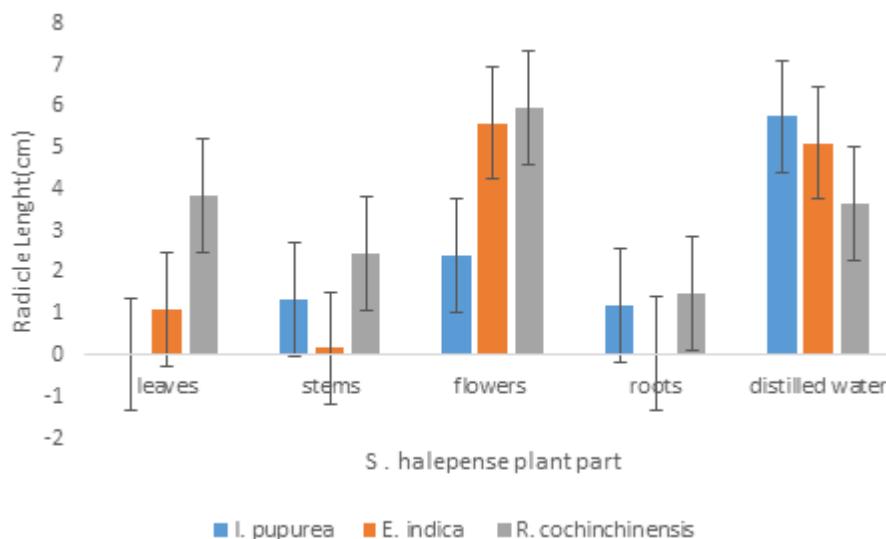


**Figure 2.** Interaction effects of *S. halepense* plant parts and weed-species-on plumule heights (seedling-growth).

radicle and plumules of the three test weeds. This implies that flowers contain low concentration of allelochemicals. It has been proven that dry matter accumulation of all test weeds had been affected by aqueous extracts of *S. halepense*. This has a detrimental effect on photosynthesis and hence, the overall productivity has been compromised (Figure 3).

The study clearly indicated that dry matter

accumulation is under threat due to infestation by *S. halepense*; that is, all the test weeds biomass was completely inhibited. The results clearly indicate that there was no significant different between the control and the flower extracts on the plumule dry matter accumulation. All the plant extracts except flower extracts inhibit dry matter accumulation amongst all the three weed species. This clearly shows that concentrations of



**Figure 3.** Interaction effects of *Sorghum halepense* plant parts and weed-species on radicle-length (cm).

**Table 2.** Interaction effect of *S. halepense* plant parts and weed species on radicle dry weight (g).

Plant part	Weed species		
	<i>Rottboellia cochinchinensis</i>	<i>Eleusine indica</i>	<i>Ipomoea purpurea</i>
Control	1.38 <sup>b</sup>	1.68 <sup>c</sup>	2.95 <sup>ce</sup>
Leaves	0 <sup>a</sup>	0 <sup>a</sup>	1.2 <sup>b</sup>
Stems	0 <sup>a</sup>	0 <sup>a</sup>	1.35 <sup>b</sup>
Flowers	1.33 <sup>b</sup>	1.35 <sup>b</sup>	2.8 <sup>e</sup>
Roots	0 <sup>bd</sup>	0 <sup>bd</sup>	1.85 <sup>cd</sup>

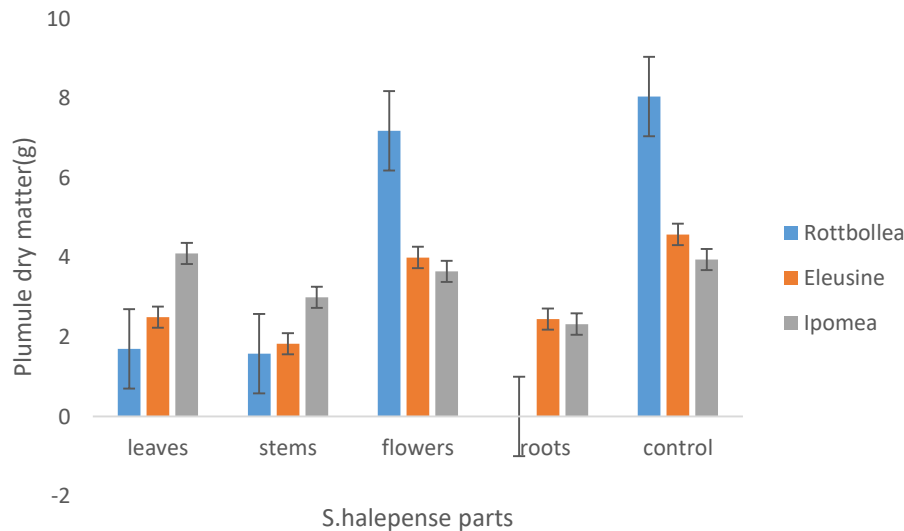
P-value < 0.001; LSD (0.05) Plant part X weed species, 0.2564; CV %, 2.5.

allelochemicals differ within the same plant depending on the part in question. Some weeds like *R. cochinchinensis* dry matter accumulation were completely inhibited by root extracts (Figure 4).

During decomposition, an increased concentration of *S. halepense* is released into the surrounding environment, which obstructs germination and growth of all nearby plants. Based on this reasoning, it can be argued that the weed should be removed from the arable land. For instance, if *S. halepenses* is left in the field, then it can completely colonize the bare soil, thus eradicating all native species, leading them to the verge of extinction. In addition, the weed possesses one of the strongest attribute of invasive species, which transforms the whole ecosystem structure and services, negatively outbalance the ecosystem for all of its competing flora and fauna because of its allelochemicals, and ultimately making it,

the sole invader of the land. Shackleton et al. (2019) also highlighted similar findings. They noted that *T. diversifolia* does contain ferulic acid, syringic acid, and chlorogenic compounds which influence morphological processes of most plants, germination included. Musyimi et al. (2015) noted that these allelochemic substances restrict the absorption of water, which in turn affect the hydrolysis of food components inside the seed resulting in poor germination. Moreover, within the complex of these allelochemic substances, particularly the extracts of *S. halepense*, there may be those which restrict the activity of the enzymes amylases and peroxidases acid phosphates, which aid the breakdown of starch.

All of the *S. halepense* parts extract suppressed *R. cochinchinensis* *I. purpurea* and *E. indica* radicles. Moreover, maximum restriction was obtained in radicle after treating with root and leaf extracts (Figure 1).



**Figure 4.** Interaction effects of *Sorghum halepense* parts and weed species on plumule dry weight (g).

Reduction of the germinated seedlings radicle length was observed due to the extracts which confirms the presence of mitotic inhibitors in the complex of allelochemicals in *S. halepense* extracts (Musabayana, 2024). Due to the *S. halepense* extracts' inhibitory effects on germination, the extension of root and shoot of the affected crops is stunted, making this weed a nuisance to the plantations. *S. halepense* has allelopathic effects against couch grass and thatch grass species. Allelopathic compounds may slow down the activity of the enzymes responsible for photosynthesis, respiration, and development, the rate at which proteins and hormones are synthesized, membrane permeability of chloroplasts as well as mineral absorption and transport from the roots to other plant parts, and even division of the cell through mitosis and DNA replication (Bano et al., 2012).

## CONCLUSION AND RECOMMENDATIONS

The study demonstrated that the leaf, stem and root extract from *S. halepense* had the maximum inhibition on seed germination, seedling growth and dry matter accumulation of the three weed species compared to distilled water. Farmers are advised to utilize the allelopathic compounds of Johnson grass in cropping systems like cover crop, smother crop, companion crop, and crop and smother crop as a way of controlling weeds. Additional research on herbicidal and allelopathic potentials of sorgholeone may be done to isolate the enzymes and accompanying genes that are responsible

for the biosynthesis of these compounds. Moreover, it becomes necessary for one to carry out genetic engineering of the identified genes in sorghum or other crops so as to enhance their weed suppressing abilities.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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