Aqueous Leaf Extracts of Sunflower (*Helianthus annuus*) for Weed Management

K. Makaza, M. Matigimu, and N. Sakadzo

Abstract Allelopathy is a phenomenon which has both beneficial and detrimental effects amongst plants within the same community. The concept is gaining popularity as a sustainable weed management tool in agro-ecosystems because of its potential to create eco-friendly products as compared to synthetic herbicides which have risks to human health and environment. A laboratory experiment was conducted at Great Zimbabwe University to evaluate the allelopathic effect of crude leaf aqueous extracts of sunflower (*Helianthus annuus* L.) on germination and early seedling growth of black jack (*Bidens pilosa* L.) seed. Four concentrations of shade dried sunflower leaf extract (2%, 4%, 6% and 8%) (w/v) were evaluated against distilled water (0%) as the control. Ten black jack seeds were sown in each petri dish per treatment and arranged in a Completely Randomized Design (CRD), replicated thrice. Results showed significant ($p < 0.05$) inhibitory effects on mean germination percentage, mean plumule and radicle length. Mean germination percentage of black jack treated with crude aqueous extracts concentrations were significantly ($p < 0.001$) lower than the control. Similarly, plumule and radicle elongation were significantly ($p < 0.001$) inhibited by the various sunflower leaf extracts concentrations. The inhibitory effect increased with increase in sunflower extract concentration. The 6% and 8% treatment concentrations had the highest inhibitory effects on all parameters as compared to the control, although they were not significantly different from each other. Whilst 4%, 6% and 8% treatment were not significantly ($p > 0.001$) different from each other on mean germination, their inhibitory effect were highly significant ($p < 0.001$) as compared to other lower treatments. Therefore, aqueous leaf extract of sunflower is allelopathic as it inhibited germination, plumule and radicle growth. The 6% concentration is recommended for use as pre-emergence herbicide against black jack. Further research using organic solvents to extract non-polar allelochemicals and efficacy of different plant parts is recommended.

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X. Poshiwa and G. Ravindra Chary (eds.), *Climate Change Adaptations in Dryland Agriculture in Semi-Arid Areas*, https://doi.org/10.1007/978-981-16-7861-5_10

Keywords Allelopathy · Aqueous leaf extract · *Helianthus annuus* · *Bidens pilosa* · Bio-herbicides · Germination · Plumule · Radicle

Introduction

Allelopathy is a natural and environmentally friendly technique which proved to be a unique tool for weed control for increasing crop yields (Sharma and Satsangi 2013). The term allelopathy was coined by Molisch in 1937 and derived from two Greek words 'allelon' which means each other and 'pathos' means to suffer or the injurious effect of one upon each other (Rawat et al. 2017). It is the biological phenomenon where the development of one plant interferes with the physiological processes of other growing plants within the same community. Pejman et al. (2011) defined allelopathy as the inhibitory or stimulatory effects of a plant or microorganism on other plants or microorganisms through the release of chemical compounds into the environment which are known as allelochemicals. Allelochemicals are biomolecules or secondary metabolites which are produced as by products by plants during their different physiological processes and they have a role in plant-plant, plant-soil, plant-pathogen, plant–insect and plant-predator interactions that may be beneficial or detrimental to the plant (Sharma and Satsangi 2013). These allelopathic compounds are non-nutritional and can be found in any part of the plant i.e. from leaves, stem, root, flower and seeds of living or decomposing plant material and they can be released to the environment as leachates, root exudates, volatiles and from decomposed material (Qasem 2012; Sharma and Satsangi 2013; Bonanomi et al. 2016). Allelochemicals can affect growth and development of plants by having multiple effects on photosynthesis, respiration, cell division, pigment synthesis, protein synthesis, production of plant hormones, membrane permeability, nitrogen fixation, germination of pollen grains and several enzyme activities (Nivas et al. 2017). They may cause necrosis of the root, poor germination, curling of the root axis, discoloration, reduced weight accumulation and lowered reproductive capacity (Mukondwa et al. 2019). The allelopathic effect between plants exists in wide array of interactions in agro-ecosystems and types of allelopathy are basically categorized with respect to the relationship between the plants species involved and these include: crop-crop, crop-weed, weed-weed and tree-crop (Signh et al. 2012).

Weeds are among the pests which are of great economic importance in the agriculture sector all over the world. These are plants that exist on undesirable location, not valued for its use or beauty but regarded as hindering the growth of the superior vegetation sown by men. Generally, crop yields are very low in communal farming sector of Zimbabwe due to crop- weed competition which result from ineffective weed control and poor timing of weed removal (after 4–6 weeks in maize) (Mukondwa et al. 2019). Black jack is one of the common problematic weeds found in arable lands of Zimbabwe. To alleviate the yield losses, most farmers are now relying on synthetic herbicides due to their high efficacy. However, the use of synthetics may have drawbacks to the environment and also cause health problems to people. Crops

have been grown since ancient years without damage to the environment but the use of synthetic herbicides during the short span of the last 50 years have raised serious doubts about their continuous use (Rawat et al. 2017). Synthetics are not easily biodegradable in the environment; hence, they cause environmental pollution which may cause adverse effects on the life of natural ecosystems. Hand weeding using a hoe is the commonly practiced weed control method in small farming sector in Zimbabwe. Mandumbu et al. (2013) propounded that weed control using hand weeding is uneconomical due to higher costs of labour and resultant low yields in the communal farming sector of Zimbabwe. A lot of time and energy is expended on removal of weeds by hand or short handled hoes. About 70% of the time of a farmer from the beginning to the end of the season is being spent on weeding (Mukondwa et al. 2019). As a result, the operation becomes monotonous and back breaking. In addition, Gianesse (2013) reported that availability of labour for hand weeding is decreasing and costs of labouris increasing, resulting in inconsistent weed control and poor crop yields.

A potential alternative for overcoming the use of herbicides and labour shortage related problems is to use allelopathic strategies in weed management for sustainable agriculture (Mukondwa et al. 2019). For sustainability, future weed control practices might consist of multiple integrated strategies of which one might be making crops suppress weeds themselves by improved allelopathy and competition and minimize or stop the use of herbicides (Rawat and Maikhuru 2012). According to Rawat et al. (2017), sustainability emphasise on optimal crop production with minimal external inputs, reducing dependence on commercial inputs (fertilizer and pesticides) and substituting them with internal resources and relying on sustainable practices which maintain the productivity over long periods. According to Farooq et al. (2011), wise exploitation of allelopathy in cropping systems may be effective, economical and natural method of weed management and a substitute for chemical control and hand weeding in improving crop productivity for communal farmers. Allelopathic crops offer strong potential for the development of cultivars that are highly weed suppressive (Pejman et al. 2011).

Sunflower has been reported to have allelopathic effects on other plants and has the potential for achieving sustainable weed management, (Sharma and Satsangi 2013). The bioassays of leaf aqueous extracts show strong inhibition in germination and root length of many weeds and crops (Rawat et al. 2011; Pejman et al. 2011). Macias et al. (2002) propounded that there are 25 natural allelopathic compounds that are phytotoxic towards many plants from different sunflower cultivars. Further studies showed that sunflower contain 16 sesquiterperne, 14 *bisnorsequiterpenes* and *sesquiterpenehilannulos* for its toxicity (Rawat et al. 2017). Leaf aqueous extracts of sunflower were found to contain five new guananolides and the annuolides possesses allelopathic activity (Rawat et al. 2011). Heliannuols, terpenoids and flavonoids are the most common important allelopathic compounds isolated from sunflowers (Pejman et al. 2011). The heliannuols and all guananolides proved inhibitory to dicot weed species, hence they may be an excellent source as a pre- and post- emergence herbicide to dicotyledons species (Rawat et al. 2011; Rawat et al. 2017; Pejman et al. 2011).

Allelopathic material from sunflower can influence the antioxidant systems in target plants causing cell membrane permeability and cellular damage, reducing the target plant's ability to germinate and causing a gradual loss of seed vigor (Pejman et al. 2011). The most frequently reported gross morphological effects on plants are inhibited or retarded seed germination and effects on coleoptiles elongation shoot and root development (Kruse et al. 2000). According to Bogatek et al. (2006), sunflower extracts completely inhibited seed germination of white mustard. Kamal (2011) reported that, sunflower extract was inhibitory to germination, shoot and root length of wheat, maize and species of weeds. Sharma and Satsangi (2013) observed that, the leaf extract of sunflower show more inhibitory effect on the growth (seed germination, plumule length, radical length) of *Parthenium hysterophus* in comparison to stem and root extract. Pejman et al. (2011) postulate that *Lolium rigidum* is sensitive to extracts of sunflower cultivars as sunflower extract reduced all traits in this weed. The aqueous extracts as well as growing plants inhibits the seed germination and seedling growth of *Abutilon theophrasti*, *Datura stramonium, Ipomoea* spp., *Brassica kaber* and also reduced the germination by 36–56% and seedling growth with 22–57% of *Trianthema portlacastrum* and *Amarantus vidris* (Rawat et al. 2017). Therefore, this study was to determine the allelopathic effects of crude aqueous leaf extracts of sunflower on germination and early seedling growth of black jack.

Materials and Methods

The study was conducted in 2020 at Great Zimbabwe University main campus in Masvingo, Zimbabwe (latitude 20°7′ 17S and longitude 30°49′ 58E; altitude of 1034 m above mean sea level) located in the agro-ecological region (IV). The study area is characterized with an annual average annual rainfall of 600 mm with mean temperature of 28 °C. Average temperature during the study was 17 °C. The lab studies were conducted at Great Zimbabwe University Chemistry laboratory in June 2020.

Sunflower variety Sy 4200 was planted at recommended spacing of 75 cm inter-row and 25 cm intra-row. During planting, Compound D was used as basal dressing at the rate of 250 kg/ha. The leaves of sunflower were harvested at 40 days after planting (Kamal 2011) and were dried for 30 days under room temperature, then powdered to increase the surface area for the particles and to speed up the extraction.

Preparations of Leaf Extracts

The powder was soaked in water in different beakers with different concentrations ranging from 2 to 8%. The concentrations were prepared as described by Sakadzo et al. (2018) by adding 2 grammes of sunflower leaf powder to 100 ml of distilled water to give 2% concentration of aqueous and 4, 6 and 8% concentrations were

prepared in the same manner. Treatment with 0% was the control with 20 ml of distilled water. The prepared extracts concentrations were left for 48 h. The solutions were filtered and stored under temperatures below 5 °C (refrigerated) until use to prevent contamination by pathogens and the conversions of crucial chemicals under high temperatures (Kamal 2011).

Experimental Design

The laboratory experimentwas conducted in a Completely Randomized Design (CRD) with five treatments (0% (control), 2%, 4%, 6% and 8% sunflower aqueous leaf extracts) replicated thrice.

Weed Germination and Seedling Growth

150 healthy seeds of black jack were collected from arable land. 10 seeds were grown in Petri dishes of 9 cm diameter replicated 3 times in completely randomized design. Cotton wool was used as the medium for germination.

Data Collection

Germination of seeds was counted after 6 days after soaking (DAS) and was expressed as a percentage. The seeds were considered germinated when the radicle and plumule started to show, following imbibition which was evidenced by an increase in seed size. Radicle and plumule length were measured in cm using a ruler at day 6 and 7.

Data Analysis

Data were analysed using Genstat version 14.1 and means were separated using Fisher's protected least significance difference (LSD) at 5% significance level.

Results

Effect of Sunflower Crude Aqueous Leaf Extracts on Mean % Germination on 7 DAS

The 4–8% sunflower extract concentration significantly ($p < 0.05$) inhibited black jack seed germination more than 2% and the control (Table 1 and Fig. 1), although

Table 1 Effects of different sunflower crude leaf aqueous extracts concentrations on mean germination, radiclelength and plumule length of black jack at 7 days after sowing (DAS)

Leaf aqueous extracts concentration (%)	Germination %	Plumule length (mm)	Radicle length (mm)
0	96.67^{c}	4.267^{d}	6.700^{c}
2	20.00^{b}	2.667^{c}	3.833^{b}
4	6.67^{a}	1.333^{b}	2.667^{b}
6	0.00^{a}	0.000^{a}	0.000^{a}
8	0.00^{a}	0.000^{a}	0.000^{a}
Grand mean	24.7	1.65	2.64
F probability	<0.001	<0.001	<0.001
LSD	10.50	1.187	2.001
% cv	23.4	39.5	41.7
Significance	**	**	**

Means followed by the same letter in the same column are not significantly different at 5% level according to Fishers protected least significant different test
ns represents non-significance, * shows significance, ** shows very high significance

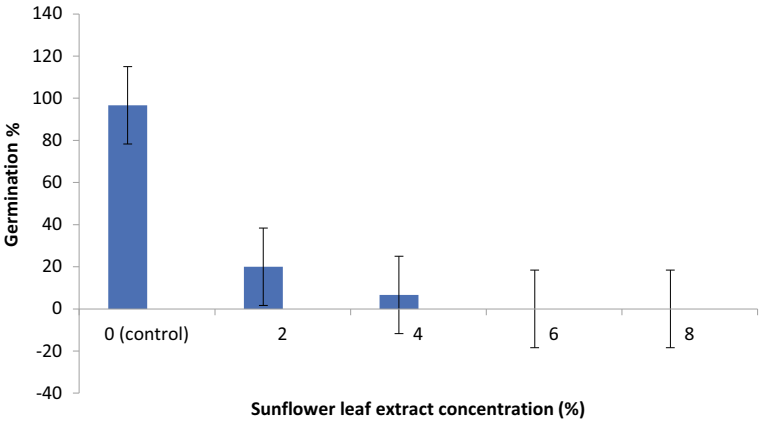

Fig. 1 Effects of sunflower crude leaf aqueous extracts on mean germination percentage of black jack seeds 7 DAS.
*Error bars which do not overlap shows significant differences and those that overlap shows no significant differences at 5%

there were no significant differences ($p > 0.05$) among themselves. Overall, germination percentage at day 7 follows a definite trend with treatment 1 (control) having the highest mean germination percentage (96.67%). 2% sunflower aqueous concentration had 20% and 4% sunflower aqueous concentrationhad 6.67%, whereas treatment 6% and 8% concentrations didn't germinate, having 0% germination mean.

Effect of Sunflower Crude Leaf Extract on Mean Plumule Length of Black Jack Seedlings 7 DAS

There were highly significant ($p < 0.001$) differences on mean plumule length due to sunflower crude aqueous extracts concentrations (Table 1, Fig. 2). The control (0%) had the highest plumule length (4.267 mm), which was significantly ($p < 0.001$) higher than 2% treatment (2.667 mm) and 4% treatment (1.3333 mm). However, the plumule length mean for 6% and 8% treatments was not significantly different.

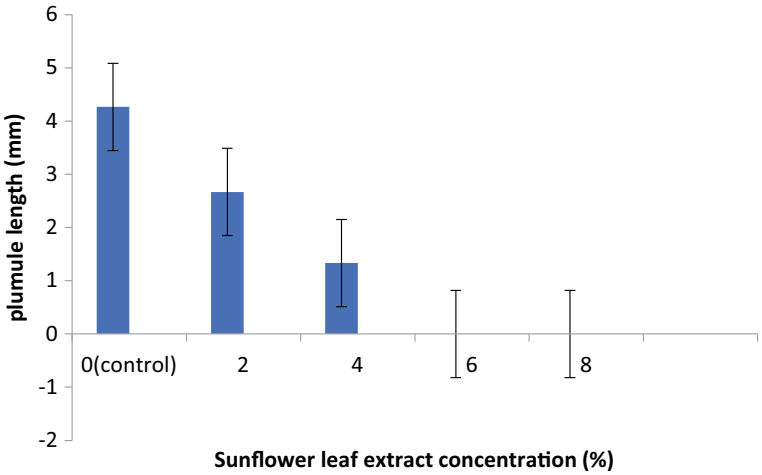

Fig. 2 Effect of sunflower crude leaf aqueous extracts on mean plumule length of black jack seedlings 7 DAS.
*Error bars which do not overlap shows significant differences and those that overlap shows no significant differences at 5%

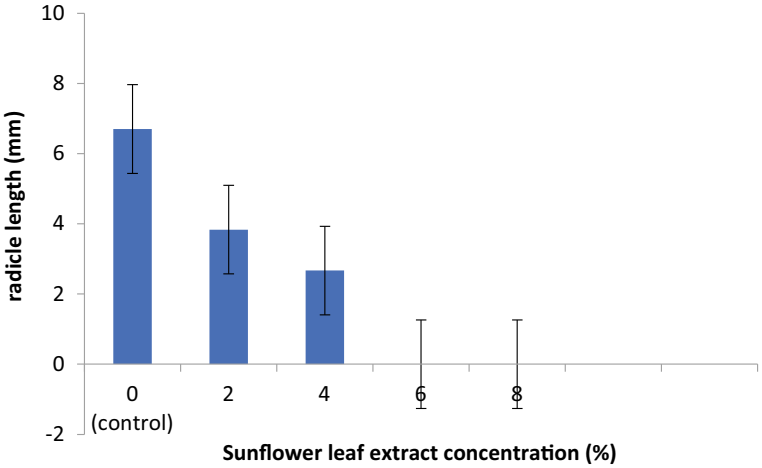

Fig. 3 Effect of sunflower crude leaf aqueous extracts on mean radicle length of black jack seedlings 7 DAS.
*Error bars which do not overlap shows significant differences and those that overlap shows no significant differences at 5%

Effect of Sunflower Crude Leaf Aqueous Extracts on Mean Radicle Length of Black Jack Seedlings on 7 DAS

The difference in mean radicle length of black jack was highly significant ($p < 0.001$) affected by sunflower crude leaf aqueous extract (Table 1 and Fig. 3). The increasing concentration of aqueous extract drastically reduced the radical length. Treatment 1 (control) had the highest mean radicle length (6.700 mm) which was significantly ($p < 0.001$) higher over rest of the treatments. Treatments with 6 and 8% aqueous concentrations were not significantly different ($p > 0.05$).

Discussion

There was highly significant difference among the treatments means on germination percentage at 7th day. The control black jack seeds were characterized by germination ability of 96.67% which was significantly higher ($p < 0.001$) than sunflower leaf extract treatments. The aqueous extracts from sunflower leaves showed inhibitory effect on black jack weed germination. The degree of inhibition increased as concentration increases. 6% and 8% treatments with the highest sunflower crude leaf extracts inhibited seed germination completely whereas 20% and 6.67% mean germination were detected in the presence of 2% and 4% leaf extract, respectively at day 7. This revealed that sunflower leaf extract successfully suppressed seed germination of black jack. Bogatek et al. (2006) also observed that germination

of mustard seeds were inhibited as concentration of sunflower extract increased, and in the presence of high concentration of sunflower leaf extracts, germination was almost inhibited completely. This means that, the higher the concentration, the more the toxic compounds such as phenolics which causes osmotic stress resulting in loss of membrane intergrity and enhancing loss in germinability. The loss in seed germinability may be a result of an increase in lipid peroxidation due to increase in malondialdehyde (MDA) which increases as concentration of sunflower leaf extract increases. In support, Bogatek et al. (2006) observed that, two cultivars of sunflower affected lipid peroxidation of mustard seed in the same way. This result reveals that loss of seed germinability is associated with membrane lipid peroxidation. Also, loss of germinability may be due to toxic interference with respiration resulting from reduced production of ATP and RNA synthesis or disturbances in the functions of secondary messengers necessary for germination (Muhammad and Majeed 2014).

This implies that, germination alterations are not only due to water stress and lipid peroxidation but the inhibition in seeds germination was greatly influenced by the presence of high concentration of toxic allelopathic compounds such as phenolics, alkaloids and flavonoids which are present in sunflower (Muhammad and Majeed 2014). This was in agreement with the research by Bernat et al. (2004) who concluded that, the lower water availability for seed germination due to binding of water molecules by compounds present in extract of sunflower leaves plays a minimal role in reducing seed germination, but the action of sunflower allelochemicals is mainly due to their toxic nature.

Sunflower leaf extract highly significantly ($p < 0.001$) suppressed the plumule growth of black jack as compared to the untreated control under laboratory conditions (Table 1 and Fig. 2). The inhibition of plumule growth was concentration depended. Similar results by various workers revealed that aqueous leaf extracts of sunflower potentially reduced the development of early seedling growth on different crops and weeds (Bogatek et al. 2006; Kamal 2011; Sharma and Satsangi 2013). Sunflower aqueous leaf extracts has been reported to be rich in toxic substances such as flavonoids, alkaloids and phenolics which altered cell division patterns, physiological function and interferes with water and mineral uptake capacity of seedlings (Muhammad and Majeed 2014). Reduced germination and delay in germination time reduced growth of the plumule.

The phytotoxicity of aqueous extracts of sunflower leaf was significantly increased as their concentration increase due to presence of high allelopathic toxic compounds (Kamal 2011; Sharma and Satsangi 2013). The leaf of sunflower has high concentration of phenolic compounds such as polyphenols, tannins and flavonoids and these substances affect phytohormones such as gibberellic acid (GA) and indole acetic acid (IAA) which are essential growth hormones, resulting in reduced growth of seedlings (Kamal 2011). Besides that, the allelochemicals of sunflower interfere with mitosis in the root apex by inhibiting enzymes necessary for adenosine triphosphate (ATP) and ribose nucleic acid (RNA) synthesis (Muhammad and Majeed 2014) and this causes cell death in roots of early seedlings, resulting in retarded growth. In support, Levizou et al. (2002) reported that sunflower leaf extracts retarded mitosis in the root apex of lettuce seedlings.

Conclusion

Sunflower aqueous leaf extracts significantly inhibited germination; plumule and radicle elongation of black jack in petri dishes.There is need for further investigation of suflower allelopathy in pots, micro pots and field situations. The study will help in developing low cost adaptation strategies for climate resilient agriculture thereby promoting an economic and eco-friendly environment to small holder farmers.

Future Research

To focus on the effects of sunflower aqueous extracts on other common arable broad leaf weeds including monocotyledonous species in Masvingo;

- Allelopathic effects of organic solvent extracts as opposed to aqueous extracts on various weeds.
- Studies on the allelopathic effects using fresh and dried morphological parts (root, stem, leaves) of sunflower in weed management should be conducted for comparison.
- Field trials and green house experiments in pots are suggested for further elucidation of allelopathic activity of sunflower on *Bidens pilosa* and other arable weeds.
- Foliar spray studies to evaluate potential of extracts as an early post emergence herbicide
- Identification and purification of allelochemicals from different parts of sunflower.

Acknowledgements We gratefully acknowledge support given by GZU Department of Soil and Plant Sciences for the lab and apparatus used in this experiment.

Mr. Richard Muza, Senior Laboratory Technician at Great Zimbabwe University deserves profound thanks for technical guidance in carrying out the experiment.

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