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THE ALLELOPATHIC EFFECTS OF SELECTED WEEDS SPECIES ON GERMINATION AND GROWTH OF MAIZE

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ABSTRACT

In Southeastern Nigeria, weeds such as *Chromolaena odorata*, *Ageratum conyzoides*, *Eleusine indica, Tridax procumbens* and *Euphorbia hirta* thrive. The decaying remnants of these weeds left on or in the soil have been found to contain a variety of chemical compounds. The effect of aqueous leaf extracts of these weeds on *Zea mays* seed germination and growth was investigated. Results of this study showed that plant species and their concentrations had a significant effect ($p<0.05$) on the parameters measured. The root length of *Z. mays* was more affected negatively by *Chromolaena odorata* than the other weed species. The inhibition of *Zea mays* seed germination by the studied aqueous extracts was as follows: *Tridax procumbens* (27.33%) > *Euphorbia hirta* (26.16%) > *Ageratum conyzoides* (23.45%) > *Eleusine indica* (22.42%) and *Chronolaena odorata* (18.73%). *Eleucine indica* had more inhibitory effect on shoot length (42.83%), seedling length (41.70%) and seedling vigour index (51.79%) of *Zea mays*. This was compared to aqueous leaf extract of *Chromolaena odorata*, *Ageratum conyzoides*, *Tridax procumbens* and *Euphorbia hirta*. The results suggest that potential allelopathic substances produced by studied weed species may hinder germination and growth of *Zea mays*.

Keywords: Allelopathy; inhibitory effect; aqueous extract; weed, phytotoxicity
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INTRODUCTION

Weeds are a persistent nuisance in agricultural settings, reducing crop productivity. Understanding the nature of weeds and their modes of activity in the environment is thus required in order to discover how to limit their impact on agricultural crops. Weeds compete with crops for resources in a variety of ways, including physically, chemically, or both.

Allelopathy is a plant growth-inhibition or stimulation process in which living or dead plant components emit or release chemical compounds that hinder or encourage the development of the linked plant (Pellissier, 2013). Allelopathic chemicals may be found in a wide range of plant tissues, including leaves, flowers, fruits, stems, roots and seeds (Farooq *et al.*, 2011). Allelopathy is a phenomenon that can have either beneficial or detrimental effects on the receiver depending on the chemical concentration and recipient plant type (Mondal *et al.*, 2015).

Several studies have shown that certain weed species have allelopathic impacts on the seed germination and seedling growth of commercially significant agricultural plants (Delabays *et al*., 2004; Mulatu *et al.*, 2009). Germination studies are crucial in establishing weed allelopathy as a significant crop interference mechanism. Because the seed is a vital plant organ that is particularly sensitive to allelochemicals, germination has long been the chosen bioassay in allelopathic research (Aliotta *et al*., 2006). Seed germination is a vital phase in the propagation and cultivation of most crop species (Ishii-Iwamoto *et al*., 2006).The effect of varying concentrations of weed leachates or extracts on percentage germination, shoot length and root length have been documented. *Chromolaena odorata*, *Ageratum conyzoides*, *Eleucine indica*, *Tridax procumbens* and *Euphorbia hirta* are some of the most common weeds in Southeastern Nigeria. The decomposing leftovers of new weeds are frequently used as mulch on the soil surface.

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Residues from crops, weeds or natural vegetation left on or in the soil are known to release a variety of chemical compounds into the soil during decomposition. Plant growth inhibitors and allelochemicals are examples (Narwal, 2006). *Zea mays* L. is one of the most regularly planted edible crops in Southeastern Nigeria. In this study, the allelopathic effects of weeds (*C. odorata, A. conyzoides, E. indica, T. procumbens* and *E. hirta*) on the germination and growth of maize seedlings were investigated.

MATERIALS AND METHODS

The experiment was carried out in the Laboratory of the Department of Applied Biology, Ebonyi State University, Abakaliki, located at latitude 6º 22'26"N and longitude 8º 6'6"E of the Greenwich meridian. The average temperature in the atmosphere is 32–35´C (Epidi *et al*., 2008). The seeds of maize (*Zea mays* var Oba Super 4) were used in the experiment. The cultivar was obtained from Umudike National Seeds Centre. The seeds were subjected to viability test. The completely randomised design (distilled water, 20%, 15%, 10% and 5% (w/v^{-1}) plant extract) was used with three replications.

Experimental Procedure

C. odorata, A. conyzoides, E. indica, T. procumbens and *E. hirta* were obtained from cropping areas and transported to the laboratory. They were validated in the Herbarium of the Department of Applied Biology, Ebonyi State University, Abakaliki, Nigeria. Clean water was used to rinse each plant material. Fresh leaves were chopped into little pieces and mashed with a mortar and pestle for each species. A 200 g powdered sample of each species was measured and steeped in 2000 ml distilled water in a separate plastic bucket for 7 days, giving a 20% (w v-1) aqueous extract. The seeds of the test crop (*Zea mays* var Oba Super 4) were treated with various doses of the weed aqueous extract. Ten seeds were placed on 8 cm diameter Petri dishes with two layers of filter paper. Using a syringe and needle, 5 ml of 5, 10, 15 and 20% aqueous extract of *Chromolaena odorata* were applied to the Petri plates on a regular basis. Sterile water was used as the control. The treatments were replicated three times. The embryo protrusion criteria were used to measure germination every 12 hours for the first seven days of the experiment. Seeds were considered as germinated upon emergence of the radicle. At 1, 2, 3, 4, 5, 6 and 7 days after sowing (DAS), the number of seeds germinated was counted, and seedling development was assessed using the following growth parameters.

i. **Germination percentage:** The method of Rehman *et al.* (2008) was used to estimate germination percentage as:

$$Germination\ \% = \frac{no\ of\ seeds\ germinated}{total\ no\ of\ seeds} x\ 100$$

ii. **Root and shoot length:** Length of root and shoot of seedlings was calculated using the standard method (Kabir *et al*., 2008).

Vigour index: The formula suggested by Abdul-Baki and Anderson (1973) was used to calculate vigour index.

iii Vigour index = $Germination\ \% \times\ (root\ length\ + shoot\ length \text{ in cm})$.

iv The method of Surendra and Pota (1978) was used to compute the percentage inhibition on germination and other growth parameters in relation to the control as follows:

$$\mathbf{I = 100\text{-}E_2/E_1 * 100}$$

Where,

I= % inhibition
E_1- Control plant
E_2- Treated plant

Statistical Analysis

Data collected were subjected to one-way analysis of variance test

RESULTS

The results revealed that leaf extracts from the tested weed species inhibited *Zea mays* germination and growth. The extent of inhibition, however, varied depending on the concentration of extracts.

Effects of plant Extracts on Percentage Germination of *Z. mays*

The percentage germination of *Z. mays* was reduced at all concentrations of the extracts tested and the degree of inhibition increased with increasing concentration (Table 1). The extracts of *C. odorata* (76.66 %), *A. conyzoides* (74 %), *E. indica* (75%), *T. procumbens* (72.67 %) and *E. hirta* (72.67%) inhibited *Z. mays* germination at the highest concentration (20 g/L). At 20 g/L, *E. hirta* and *T. procumbens* had the highest inhibitory impact on *Z. mays* germination. At concentrations of 5–20 g/L, *C. odorata* had no significant impact (p>0.05) on the percentage germination of the test crop. However, the aqueous leaf extracts of *C. odorata, A. conyzoides*, *E. indica, T. procumbens* and *E. hirta* had a significant inhibitory impact (p<0.05) on the percentage germination of *Z. mays*.

Table 1: Effects of aqueous leaf extracts of selected weed species on percentage germination of *Zea mays*

Weed Species	Concentrations of aqueous leaf extract (%)					F value	P value
	Control	5	10	15	20		
C. odorata	$94.33±1.20^a$	$86.00±2.08^a$	$83.33±6.66^a$	$80.00±5.77^a$	$76.66±3.33^a$	2.39	0.12
A. conyzoides	$96.67±3.33^a$	$94.00±1.15^a$	$89.67±0.33^b$	$80.00±0.56^c$	$74.00±0.60^d$	35.64	0.00
E. indica	$96 .67±3.33^a$	$91.00±2.08^a$	$85.67±2.96^b$	$82.00±3.06^c$	$75.00±2.69^d$	8.23	0.00
T. procumbens	$100.00±0.00^a$	$94.00±2.08^b$	$81.33±1.86^b$	$77.67±1.45^d$	$72.67±1.20^e$	57.93	0.00
E. hirta	$86.67±3.33^a$	$81.00±2. 08^a$	$73.00±3.00^b$	$67.33±3.93^c$	$64.00±4.00^d$	7.92	0.00

Values in the rows followed by the same letter(s) are not significantly different (p = 0.05)

Effects of plant extracts on shoot length of *Zea mays*

Table 2 shows the effects of aqueous leaf extracts of selected weed species on the shoot length of Zea *mays* Compared to the control in all the plant species, the shoot length decreased as the concentration of the plant extract increased up to 20 % . The application of the leaf extract of *Chromolaena odorata* resulted in a significantly lower shoot length at 20 % concentration (6. 39 ± 0. 90 cm) than at the other levels of concentration. The shoot length of *Zea mays* did not differ significantly (p> 0.05) with the level of concentration when the leaf extract of *Ageratum conyzoides* was used. Using the leaf extract from *Eleusine indica,* the shoot length ranged from 11. O9 ± 0.59 cm in the control to 6. 43 ± 0080 cm and the difference (p > 0.5) was significant. The shoot length of *Zea mays* was similar irrespective of the concentration of the leaf extract of *Tridax procumbens*. The highest shoot length of 11. 57 ± 1.16 cm was observed in the control while the lowest value of 7.14 ± 0.48 cm was observed at 20 % concentration when the leaf extract of *Euphorbia hirta* was used.

Table 2: Effect of aqueous leaf extracts of selected weed species on shoot length of *Zea mays*

Weed Species	Concentrations of aqueous leaf extract (%)					F value	P value
	Control	5	10	15	20		
C. odorata	9.62±0.93[a]	9.38±1.11[a]	8.69±1.04[a]	7.45±1.10[a]	6.39±0.90[b]	1.78	0.14
A. conyzoides	11.66±0.81	9.86±1.10	9.65±1.29	8.66 ±1.21	7.87±1.18	1.58	0.18
E. indica	11.09±0.59[a]	9.99±1.00[a]	8.60± 0.99[b]	7.09±0.77[c]	6.43±0.86[d]	6.07	0.00
T. procumbens	11.03±0.76[a]	10.79±0.59[a]	9.91±0.98[a]	8.98±0.97[a]	8.84±0.85[a]	1.38	0.24
E. hirta	11.57±1.16a	11.06±0.99[a]	9.45±1.06[a]	8.58±0.65[b]	7.14±0.48[b]	4.00	0.00

Values in the rows followed by the same letter(s) are not significantly different (p = 0.05).

Effects of plant extracts on root length of *Zea mays*

The root length decreased as the concentration of the leaf extracts of plant species increased up to 20 %. The root length did not differ significantly with the concentration of the leaf extracts of *C. odorata* and *A. conyzoides*. The highest root length (10. 79 ± 0. 76 cm) was observed under the control, while the lowest (5. 87 ± 0.67 cm) was observed at 20 % concentration of the leaf extract of *E. indica*. The same trend was observed when the leaf extracts of *T. procumbens* and *E. hirta* were applied (Table 3).

Table 3: Effects of aqueous leaf extracts of selected weed species on root length of *Zea mays*

Weed Species	Concentrations of aqueous leaf extract (%)					F value	P value
	Control	5	10	15	20		
C. odorata	10.35±1.26[a]	9.74±1.01[a]	8.17±1.02[a]	7.02±1.04[a]	5.33±0.85[a]	3.79	0.01
A. conyzoides	12.89±0.93	12.46±1.32	10.79±1.48	10.13±1.50	9.73 ± 1.42	1.08	0.18
E. indica	10.79±0.76[a]	10.30±0.70[a]	6.11±0.76[b]	6.03±0.76[c]	5.87±0.67[d]	11.60	0.00
T. procumbens	14.68±0.68[a]	12.98±1.08[a]	12. 67±1.08[a]	10.58±1.05[b]	10.30±1.17[b]	3.11	0. 02
E. hirta	8.29±0.69[a]	6.99±0.60[a]	6.88±0.69[a]	5.94±0.62[b]	5.28±0.49[b]	3.354	0.01

Values in the rows followed by the same letter(s)are not significantly different (p = 0.05).

Effects of aqueous leaf extracts of selected weed species on the seedling length of *Zea mays*

Table 4 shows the effects of aqueous leaf extracts of selected weed species on the seedling length of *Zea mays*. The weed seedling length of *Zea mays* decreased as the concentration of the aqueous leaf extracts of the weed species increased and the difference (p >0.05) was significant except with the application of the leaf extract of *Ageratum conyzoindes*. Irrespective of the concentration of the plant extracts used, the highest seedling length was observed when the leaf extract of *T. procumbens* was used.

Table 4: Effects of aqueous leaf extracts of selected weed species on seedling length of *Zea mays*

Weed Species	Concentrations of aqueous leaf extract					F value	P value
	Control	5	10	15	20		
C. odorata	19.75±2.31[a]	19.37±1.87[a]	16.87±2.02[a]	14.48±2.09[a]	11.90±1.74[b]	2.72	0.03
A. conyzoides	24.45±1.61	22.36±2.36	20.44±2.76	18.86±2.66	17.80±2.60	1.21	.310
E. indica	21.40±1.19[a]	20.79±1.68[a]	14.72±1.68[b]	13.30±1.30[c]	12.46±1.55[d]	8.87	0.00
T. procumbens	25.48±1.17[a]	23.76±1.74[a]	21.92±1.99[a]	19.42±1.82[a]	19.28±2.08[a]	2.271	0.06
E. hirta	18.44±1.81[a]	18.06±1.56[a]	16.89±±1.29[a]	15.38±1.64[a]	12.10±0.86[b]	3.052	0.02

Values in the rows followed by the same letter(s) are not significantly different (p = 0.05).

Effects of aqueous leaf extracts of selected weed species on the seedling vigour index of *Zea mays*

The seedling vigour index decreased as the concentration of the aqueous leaf extracts of the plant species increased up to 20% and the difference ($p<0.05$) was significant in all but *Ageratum conyzoides* (Table 5). In all the plant species, the highest seedling vigour index was observed in the control while the least was observed at 20 % concentration of the leaf extract. Irrespective of the concentration of the leaf extracts, the highest seedling vigour index was observed when the leaf extract of *T. procumbens* was used. The use of the aqueous leaf extract of *E. hirta* resulted in the lowest seedling vigour index in the control and at 5 % concentration. The lowest vigour index was observed at 10, 15 and 20 % concentration when the leaf extracts of *E. indica* and *C. odorata* were used (Table 5).

Table 5: Effects of aqueous leaf extracts of selected weed species on seedling vigour index of *Zea mays*

Weed Species	Concentrations of aqueous leaf extract (%)					F value	P value
	Control	5	10	15	20		
C. odorata	19.75±2.31[a]	19.37±1.87[a]	16.87±2.02[a]	14.48±2.09[a]	11.90±1.74[b]	2.72	0.03
A. conyzoides	24.45±1.61	22.36±2.36	20.44±2.76	18.86±2.66	17.80±2.60	1.21	.310
E. indica	21.40±1.19[a]	20.79±1.68[a]	14.72±1.68[b]	13.30±1.30[c]	12.46±1.55[d]	8.87	0.00
T. procubens	25.48±1.17[a]	23.76±1.74[a]	21.92±1.99[a]	19.42±1.82[a]	19.28±2.08[a]	2.271	0.06
E. hirta	18.44±1.81[a]	18.06±1.56[a]	16.89±1.29[a]	15.38±1.64[a]	12.10±0.86[b]	3.052	0.02

Values in the rows followed by the same letter(s) are not significantly different (P = 0.05).

Comparative effects of aqueous leaf extracts of weed species on germination and growth of *Zea mays* seedlings

Germination

Figure 1 shows the comparative effects of leaf extracts of some weed species on seed germination in *Zea mays* at the concentration of 20%. The aqueous leaf extract of *T. procumbens* inhibited germination the most (27.33%), followed by *E. hirta* (26.16%), *A. conyzoides* (23.45%), *E. indica* (22.42%) and *C. odorata* (18.73%).

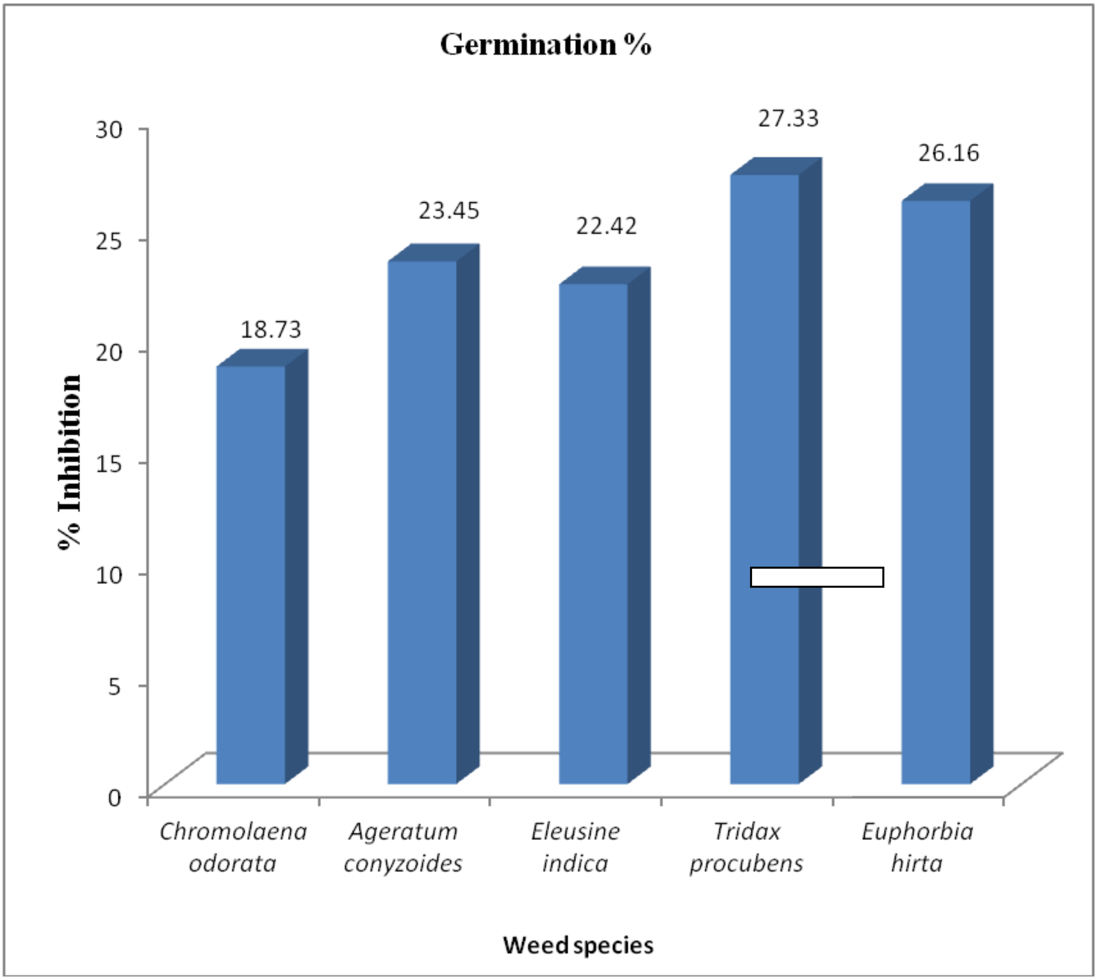

Figure 1: Comparative effects of 20 % aqueous leaf extracts of selected weed species on percentage germination in *Zea mays* at 7 days after sowing

Shoot Length

Figure 2 shows the comparative effects of aqueous leaf extracts of weed species on shoot length of *Z. mays* at 20% concentration. The highest reduction in shoot length was observed when the aqueous leaf extract of *E. indica* was used (42.83 %), followed by *E. hirta* (38.29 %), *Chromolaena odorata* (33.58 %), *Ageratum conyzoides* (32.50 %) and *Tridax procumbens* (32.50 %).

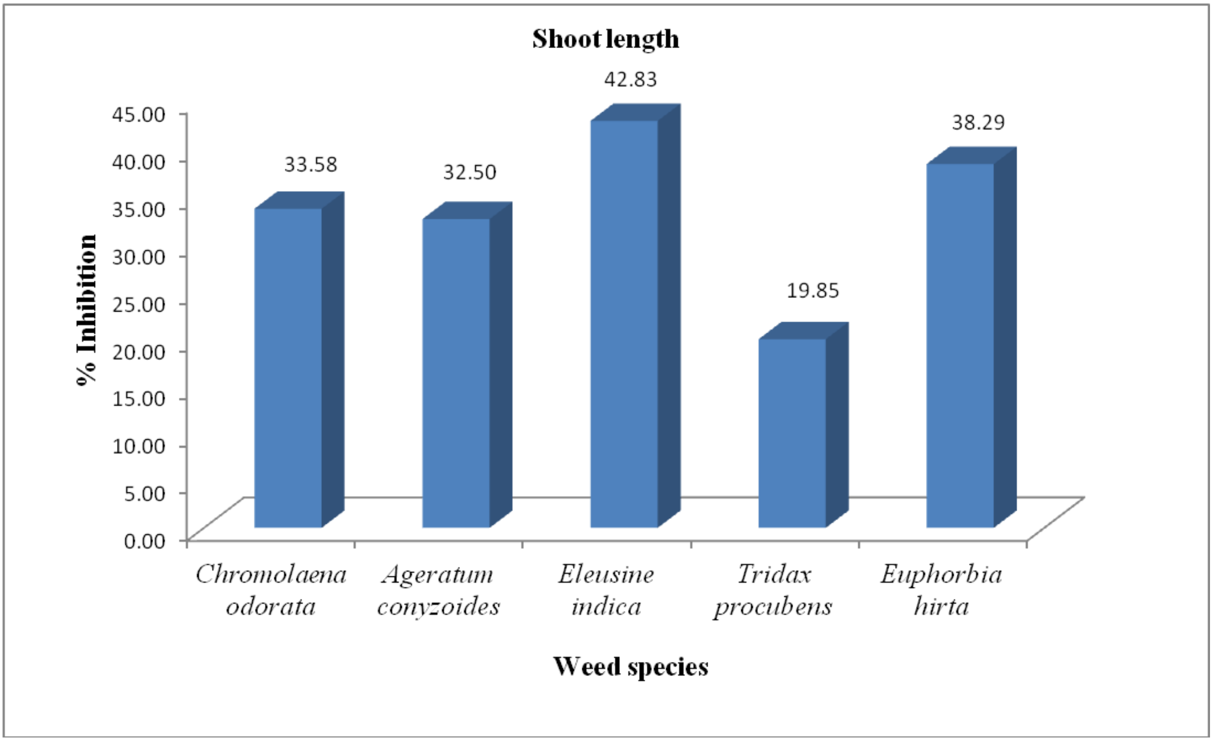

Figure 2: Comparative effects of 20 % aqueous leaf extracts of selected weed species on shoot length of *Zea mays* at 7 days after sowing

Root length

Figure 3 shows the comparative effects of the aqueous leaf extracts of some weed species on root length in *Z. mays* at 20% concentration. The aqueous leaf extract of *C. odorata* was observed to have resulted in the highest suppression of root length (48.00%), followed by *E. indica* (45.00%), *E. hirta* (36.00%), *T. procumbens* (29.00%) and *A. conyzoides* (24.00%).

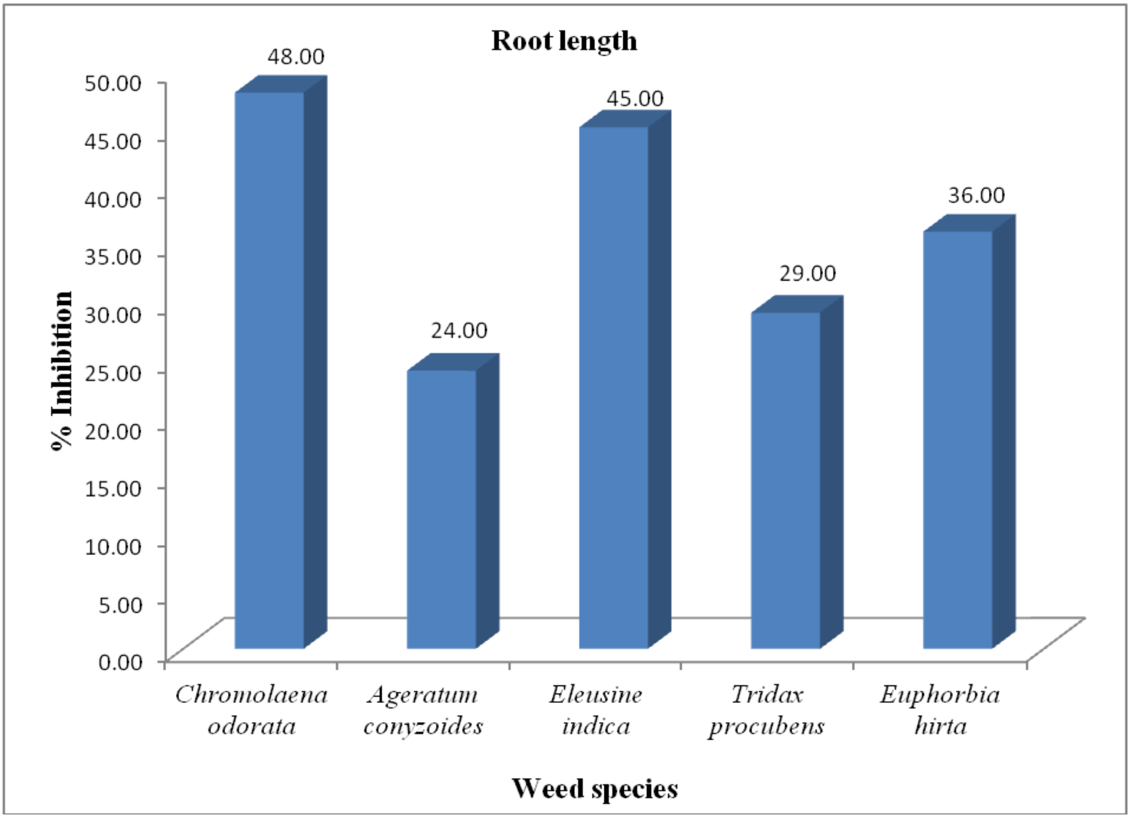

Figure 3: Comparative effects of 20 % aqueous leaf extracts of selected weed species on of root length in *Zea mays* at 7 days after sowing

Seedling length

Figure 4 shows the comparative effects of the aqueous leaf extracts of some weed species on seedling length of *Z. mays* at 20% concentration. The aqueous leaf extract of *E. indica* (41.70 %) inhibited seedling length the most, followed by *C. odorata* (39.70 %), *E. hirta* (34.30 %), *A. conyzoides* (27.10 %) and *T. procumbens* (24.30 %).

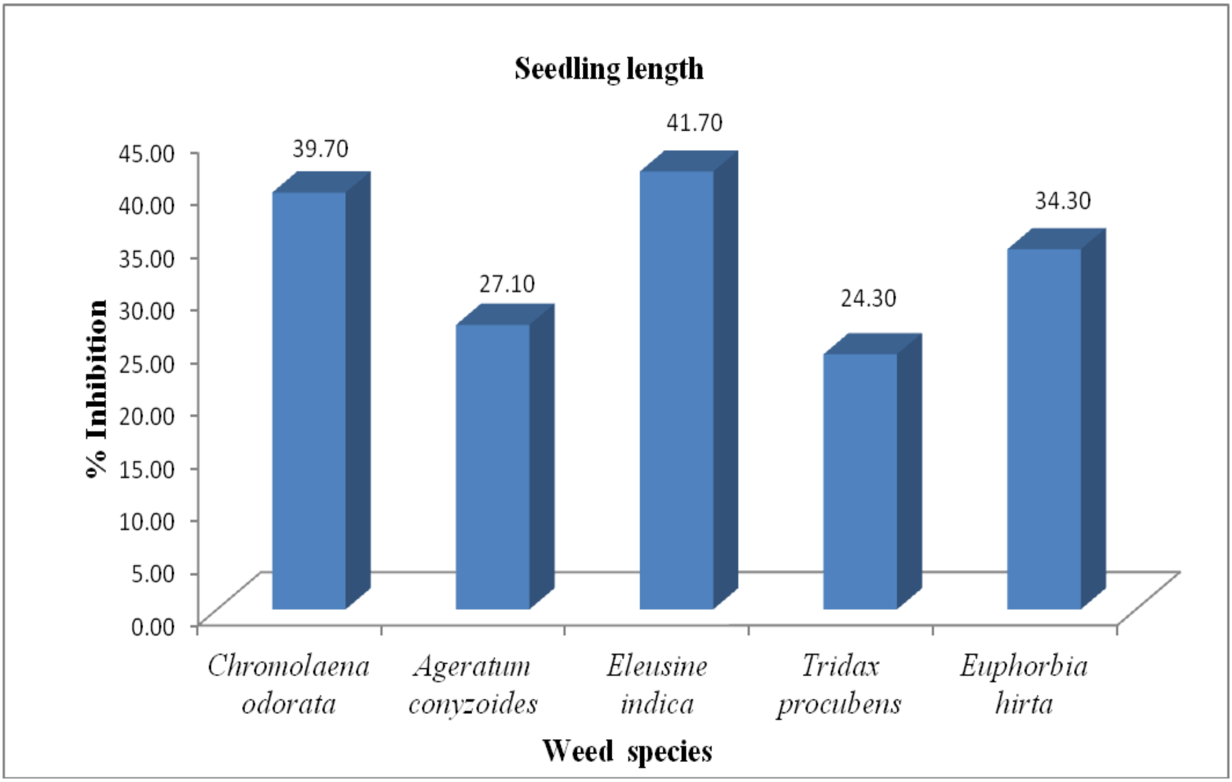

Figure 4: Comparative effects of 20 % aqueous leaf extracts of selected weed species on seedling length in *Zea mays* at 7 days after sowing

Seedling vigour index

Figure 5 shows the comparative effects of the aqueous leaf extracts of some weed species on seedling vigour index of *Z. mays* at 20% concentration. The aqueous leaf extract of *E. indica* was observed to have resulted in the greatest suppression of seedling vigour index (51.79 %), followed by *C. odorata* (46.70 %), *E. hirta* (45.30 %), *A. conyzoides* (42.82 %) and *Tridax procumbens* (34.37 %).\

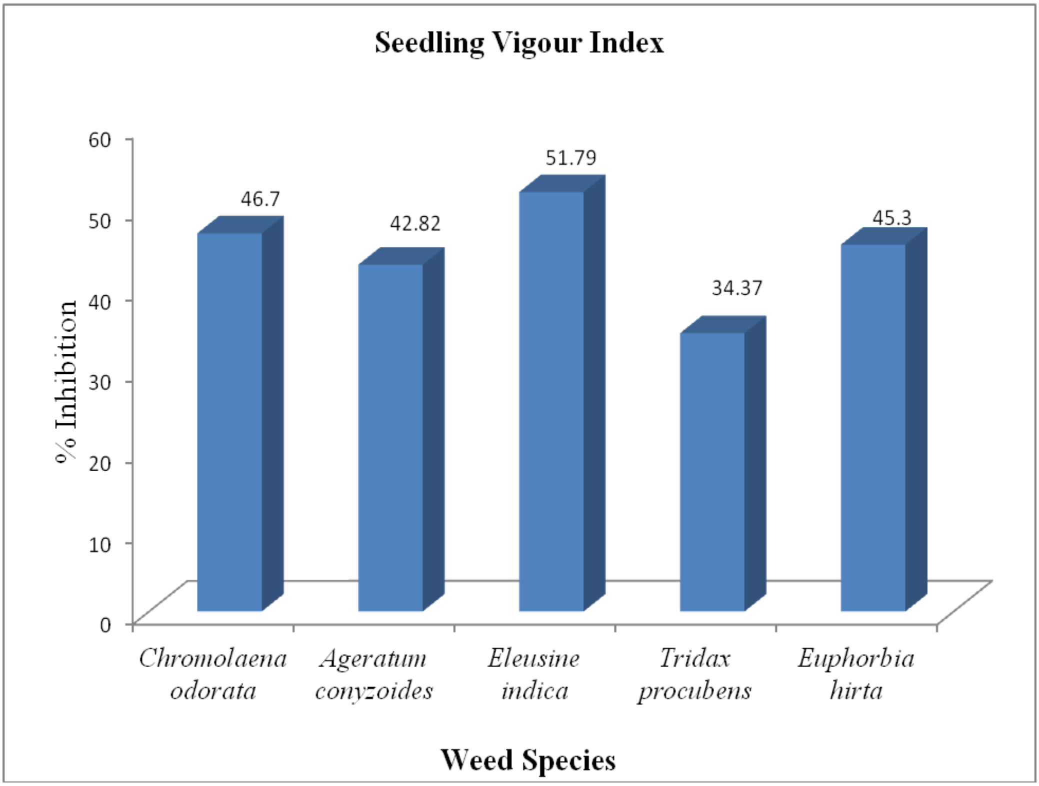

Figure 5: Comparative effects of 20 % aqueous leaf extracts of selected weed species on seedling vigour index in *Zea mays* at 7 days after sowing

DISCUSSION

Allelochemicals produced by plants (through leaching, volatilisation, exudation or residue decomposition) are a frequent stressor that can affect seed germination, plant development and nutrient absorption in related species (Bhowmik and Doll, 2004). Allelochemicals, which can be released directly or indirectly from live plants, dead plants, or organic wastes, can have a positive or negative impact on other plants.

The inhibitory impact of *Chromolaena odorata* on *Zea mays* seed germination and seed growth was clearly demonstrated in this study. *Zea mays* seedling germination and total seedling growth were significantly reduced by the extract. The least suppression was seen at a concentration of 5%, while the highest suppression was observed at a concentration of 20%. Ayeni and Kayode (2014) reported that the effects of the extracts were concentration-dependant. This finding is consistent with Kayode and Ayeni (2009) who reported that aqueous extracts from sorghum stem and rice husks inhibited maize seed germination significantly. Shahid *et al.* (2006), observed that several plant extracts inhibited wheat germination and associated weeds. Grisi *et al.* (2012) reported that extracts of *Sapindus saponaria* leaves effectively inhibited the germination of barnyard grass and morning glory diaspores. *G. sepium* extracts induced a considerable delay in maize seed germination (Oyun, 2006).

When compared to the control, the treatment with aqueous extract of *T. procumbens* resulted in a consistent reduction in seed germination, root length, shoot length, seedling length and seedling vigour index of *Zea mays*. The presence of allelochemicals in *Tridax procumbens* may be responsible for the decrease in these parameters. Rafigul *et al.* (2003) reported that the control had the highest germination percentage of all the crops studied. Ghodake *et al.* (2012) investigated the allelopathic effect of *Euphorbia* species on wheat germination and observed inhibition in germination percentage and root-shoot length. The effect of several weed extracts on seed germination, radicle, plumule length, biomass of *Zea mays* and seedlings have been reported by Gella *et al*. (2013). The seed vigour index of weed extracts decreased as concentrations increased (Mohammadi *et al.,* 2008). The concentrations of aqueous extract of *Tridax procumbens* significantly reduced root and shoot length. Allelochemicals responsible for root and shoot length inhibitions have been identified as phenolic compounds (Rimando *et al.,* 2011). Uremis *et al.* (2015) reported a similar inhibitory effect of *Tridax procumbens* aqueous extract on sorghum. Cheema *et al.* (2009) observed that the aqueous extract of *T. procumbens* reduced cotton density and biomass significantly.

The study showed that the aqueous extract of *E. hirta* inhibited the germination and growth of maize seedlings. The higher the concentration of *E. hirta* aqueous extract on maize, the higher the inhibitory effect. These findings are in line with those of Otusanya *et al.* (2015), who observed that varying *T. diversifolia* and *C. odorata* greatly reduced the germination of the seeds of *H. sabdariffa.* Ilori *et al.* (2010) observed that the aqueous extract of *C. odorata* significantly reduced germination, plumule and radicle length in *Vigna unguiculata*. Tefera (2002) observed that a 10% leaf aqueous extract of *Parthenium hysterophorus* effectively suppressed the germination of *Eragostis tef* seeds. The allelochemicals in the aqueous extracts either prevented embryo development or slowed the mitotic process of the seeds (Marharjan *et al.,* 2007). The allelopathic suppression of germination might be caused by phenolic compounds in the aqueous extracts which inhibit water intake and alter gibberellic acid production or activity (Olofsdotter, 2001; Tawaha and Turk, 2003; Otusanya and Ilori, 2012). *Zea mays* radicle and plumule growth was considerably reduced by the aqueous extract of *E. hirta*. The radicle and plumule inhibition increased as the concentration of the aqueous extract was increased. This is in line with the findings of Turk *et al.* (2003), who observed that increasing the concentration of the extract solution of the fresh plant parts of Black mustard inhibited the radicle and plumule development of wild oat. The development of the plumule was greatly delayed in this study compared to that of the radicle. The suppression of the radicle by the aqueous extracts might be due to direct interaction of the radicle with allelochemicals in the extract, which could interfere directly with respiration or oxidative phosphorylation (Sasinath *et al.,* 2006).

The application of the aqueous leaf extract of *A. conyzoides* resulted in a significant decrease in seed germination rate in maize. Similarly, the root length, shoot length and seedling length of *Z. mays* were significantly reduced. Bhatt *et al*. (2001) reported that 2 % concentration of *A. conyzoides* had an inhibitory impact on the radicle and plumule of cereal crops. Hu and Kong (1997) observed that the aqueous extract of *A. conyzoides* suppressed *Z. mays* germination, fresh weight, root length and shoot height. The allelochemicals observed in the plant leaves may be responsible for the inhibitory actions. Phenolic acids, such as p-coumaric, gallic, ferulic, p-hydroxybenzoic, anisic and syringic, have been found in *A. conyzoides* from various parts of the weed and they are all known to have allelopathic impact on other plants (Chou *et al.*, 1998).

CONCLUSION

The delayed germination and low germination rate of *Z. mays* after treatment with the aqueous extracts of *C. odorata, T. procumbens, E. hirta*, *E. indica* and *A. conyzoides* might be due to allelochemicals present in the extracts, which released phenolics into the soil. These phenolics likely inhibited the growth of surrounding plants. Aqueous leaf extracts of *C. odorata, T. procumbens, E. hirta, E. indica* and *A. conyzoides* have a wide range of activities and contain allelopathic compounds with high potential to control weed. These could be used instead of chemical compounds.

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