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Allelopathic effect of extracts from selected weeds on germination and seedling growth of cowpea (*Vigna unguiculata* (L.) Walp.) varieties

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***Chromolaena odorata*, *Euphorbia heterophylla* and *Tridax procumbens* are common weeds that are prevalent in cowpea fields. The physiological influence of three dilution concentrations of the aqueous root and shoot extracts of the weeds were examined on seed germination, plumule length, radicle length, fresh and dry weights of plumule and radicle of two varieties of cowpea in the laboratory. The experiment was laid out in a completely randomized design replicated three times. Results revealed susceptibility of two varieties of cowpea (*Vigna unguiculata* L. Walp) (IT99K-573-1-1 and IT07K -292-10) to the allelopathic potential of all the extract concentrations of the selected weeds. Although, all the extracts reduced germination and seedling growth, shoot extracts at 75% concentration of the selected weeds significantly inhibited germination and seedling growth of the variety IT99K-573-1-1 compared with the control which produced 97% (germination %); *C. odorata, E. heterophylla and T. procumbens* shoot extracts produced 22, 20 and 50% germination, respectively. Consequently, *C. odorata, E. heterophylla* and *T. procumbens* shoot extracts produced 25, 18 and 28% germination respectively for variety IT07K -292-10 while the control yielded 99%. Bioassays also indicate that the inhibition was concentration dependent; the inhibition in the extract-treated seeds increased with the increase in the concentration of the extracts. Also, the degree of seed germination inhibition was higher in shoot extracts than root extracts of selected weed. It was clear from the investigation that the extracts of *E. heterophylla* exerted a stronger inhibitory effect on the germination process and seedling growth of the two cowpea varieties than that of *C. odorata* and *T. procumbens*.**

Key words: Allelopathy, allelochemicals, *Chromolaena odorata*, *Euphorbia heterophylla, Tridax procumbens.*

INTRODUCTION

Weed infestation has been known to cause considerable reductions in crop yields thereby hindering sustainable agriculture. Weeds affect crops negatively by competing for nutrients, water, light and space; and also by releasing certain chemicals, which lead to the inter- and intra-plant chemical interactions (Rashed-Mohassel et al.,

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2001). Allelopathy is the ability of a plant to stimulate or inhibit the growth of other nearby plants through the production of allelochemicals (Torres et al., 1996; Javed, 2020). The inhibiting effects of these compounds depend on the concentration received by the affected plants and the susceptibility of the receiving plants (Koocheki et al., 2001). Studies have shown that allelopathy is a major mechanism by which weeds influence the growth of crops (Martin and Smith, 1994). Allelochemicals are most commonly found in plant extracts and in plant residues, some were found in live plant exudates and as volatile gases liberated from leaves (Rice, 1984, Ilori and Otusanya, 2013). Earlier works have shown that allelopathy plays an important role in weed and weed interaction (Kohli et al., 1998; Tajuddin et al., 2002) and weed-crop interaction (Ilori and Otusanya, 2013; Usuah et al., 2013). The study of the effects of allelochemicals produced by certain plants on other plants (weeds on crops, crops on weeds, weeds on weeds and crops on crops) has received increasing attention over the years (Rice, 1984, Marcı´as et al., 2004; Vasilakoglou et al., 2005; Dhima et al., 2006). Several studies have shown that growth cessation by allelopathic compounds covered all life stages from seed until plant maturity; seed germination, seedling growth, leaf area, dry matter, fruit production and biochemical constituents are all affected (Ogbe et al*.,* 1994; Ilori and Otusanya, 2013). Weeds are exerting allelopathic effects on crop seed germination and growth by releasing water-soluble compounds into the soil (Singh et al., 2004). *Chromolaena odorata* in the family Asteraceae has been reported to be a highly invasive weed due to its heavy seed production and aggressive growth rate (Zachariades et al*.,* 2009). Tijani-Eniola and Fawusi (1989) reported on the allelopathic activities of crude methanol extract of *C. odorata* on seed germination and seedling growth of tomato (*Lycopersicum esculentus* L.). Large amounts of allelochemicals such as phenols, tannins, flavonoids in the leaves of *C. odorata* were reported to have an inhibitory effect on the growth of many plants in nurseries and plantations (Eze and Gill, 1992). Moreover, Otusanya et al*.* (2015) and Rafiqul- Hoque et al. (2003) found that different concentrations of *C. odorata* leaf aqueous extract significantly inhibited the germination, root and shoot elongation and development of lateral roots of some plants including cowpea *Vigna unguiculata.* Also*, t*reatment with higher concentrations of inflorescence extract of *C. odorata* had more inhibitory effect on cowpea seed germination (Binumol and Santhoshima, 2018)*.* Similarly*,* Muzzo et al. (2018) reported that *C*. *odorata* leaf extract inhibited seed germination and seedling growth of some varieties of cowpea and pasture species. Prasada et al*.* (2014) investigated the effects of *Tridax* leachate on the growth of *Vigna mungo* L. and discovered that the increase in leachate concentrate was associated with the increased reduction of seed germination and seedling growth of the test crop. Similarly, several studies revealed that inhibitory effect increases with extract concentration; for example, the leaf extracts of *C. odorata* and *Lantana camara* suppressed the growth and germination of *Vigna radiata* seedlings, and the inhibitory effect was directly proportional to extract concentration (Julio et al., 2019). *E. heterophylla* (Milk weed) and other members of Euphorbiaceae family are well known for the production of a large number of secondary metabolites (Dhole et al., 2011; Saeid et al., 2010). *E. heterophylla* had been reported to be a major weed in soybean cultivation in the United States and Brazil; and it is also a major weed of cowpea (Moore et al., 1990; Winkler et al., 2003). The plant has been found to become resistant to herbicides (Falodun and Agbakwuru, 2003). The aqueous and extracts by ethanol of root, stem and leaf of *E. heterophylla* L. were found to have an effect on seed health (Dhole et al., 2013). Soybean and peanut have suffered yield losses of 30 and 50%, respectively, due to the presence of *E. heterophylla* (Bridges et al., 1992; Willard and Griffin, 1993).

Cowpea (*Vigna unguiculata* (L.) Walp.) is a tropical annual herbaceous legume (family Fabaceae) grown predominantly in Africa and is an important staple crop providing an affordable source of protein (Muranaka et al., 2016). Cowpea is the second most important food grain legume crop in tropical Africa including Nigeria, Niger, Burkina Faso, Uganda and Senegal in nearly all Africa countries south of the Sahara (Onwuem and Sinna, 1990). All parts of the cowpea crop are used, because all are rich in nutrients and fiber. Cowpea is an excellent and inexpensive source of protein, fatty acids, essential amino acids, vitamins and minerals (Fagreia et al., 1990), especially for the poor people in the third world. As a legume crop, the cowpea fixes atmospheric nitrogen through symbiotic interactions with soil rhizobia (Sarr et al., 2015). This implies that cowpea does not need to compete with weed for soil nitrogen, yet it is widely reported that its productivity is greatly constrained by weed activity. Previous studies conducted in Nigeria indicated that weeds and other crops have allelopathic effects on cowpea. Kayode and Ayeni (2009) investigated the allelopathic effects of sorghum and rice husks on cowpea and reported that both types of husks significantly inhibited germination and seedling emergence of cowpea, with sorghum having the greatest effect. Masum et al. (2012) studied the effect of *Parthenium hysterophorus* and *C. odorata* on seed germination and seedling growth of maize (*Zea mays* L.), soybean (*Glycine max* L.) and cotton (*Gossypium hirsutum* L.) under laboratory conditions. Significant inhibition of seed germination by these invasive weeds due to their allelopathic potential was reported with the highest inhibitory effect from aqueous leaf extract of *C odorata* on maize. These included the earlier work of Ogbe et al. (1994) on *C. odorata,* Kayode and Adelawo

(1997) on *E. heterophylla* and Kayode (2004) on *Aspillia africana*.

This study was carried out to (i) determine the allelopathic effects of water extracts of both shoots and roots of *C. odorata*, *E. heterophylla* and *Tridax procumbens* on germination, and growth of plumule and radicle of two varieties of *Vigna unguiculata* L.Walp. (ii) screen the extracts from the weeds for their phytochemical constituents and (iii) compare the allelopathic potential of the extracts of both fresh shoot and root of the three weeds.

MATERIALS AND METHODS

This study was conducted at the Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria, at latitude 07°30'N- 07°35'N and longitude 04°30' - 04°04'E. Two varieties of cowpea were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State of Nigeria. Milk weed *(E. heterophylla), T. procumbens and* Siam weed (*C. odorata)* seeds were collected from the demonstration farm of Olashore International School, Iloko-Ijesa, Osun State, Nigeria, at latitude 7°39^1 15.32'N and longitude 4°48^1 57.4'E.

Preparation of extracts

The preparation of the aqueous extracts of the weed species was carried out as described by Jafari et al. (2007). Roots and shoots of each weed species were collected separately. For each species, 250 g of the fresh shoots and roots were cut into small segments of about four-cm lengths and finely ground with a mortar and pestle. The ground plant material was soaked in 2 L of water for 12 h. The solution was filtered through cheese cloth to remove debris and the filtrate was further filtered through Whatman No. 1 filter paper. The final extract solution, which served as stock (100%) was diluted appropriately with water to give 75, 50 and 25% concentrations of the aqueous extracts; while distilled water was used as the control. The three dilutions of extract from root and shoot of each of the weeds were considered as treatments used in this experiment. The filtrates were kept in the refrigerator for 7 days to maintain its freshness and to prevent degradation of its allelochemicals, after which another set was prepared. Phytochemical screening for alkaloids, phenols, tannins, flavonoids, saponins, terpenoids, and glycoside was carried out according to the methods of Sofowora (1984).

Experimental layout

A total of 24 shoot and root aqueous extracts was used. Four different concentrations of each of root and shoot aqueous extract of each weed species were obtained. These extracts were applied to the seed of the two varieties of cowpea as explained in the Germination Test. Being a laboratory study, the experiment was considered as a 2 x 2 x 3 x 4 factorial experiment laid out in a completely randomized design with three replicates. Significant means were separated using standard error bars in the line graphs and New Duncan Multiple Range test at 0.05 level of probability.

Germination test

Cowpea seeds were decontaminated by soaking for 10 min in 5% sodium hypochlorite, rinsed for five minutes in running water and finally washed in distilled water. Ten uniform sized seeds of cowpea IT99K-573-1-1 and IT07K -292-10 were randomly selected and placed in each of 120 clean, oven dried Petri dishes (100 x 15mm) which were lined with Whatman No. 1 filter paper. The filter paper served as an absorbent for water or the weed extract that was used as treatment. Twelve Petri dishes were moistened with 5 ml distilled water and served as the control while the other 108 Petri dishes were allotted to different weed extracts. Each was moistened with the 5 ml of the extract. The experiment was arranged using a completely randomized design with three replicates. The entire experiments were kept at room temperature (26°C) for nine days. Germination was determined by counting the number of germinated seeds at 24-h intervals over a 9-day period. Germination Percentage (GP) was calculated with the formula:

$$GP = \frac{\text{Number of Germinated Seeds}}{\text{Number of Planted Seeds}} \text{ X } 100$$

Emergence of 1 mm radicle length was used as the criterion for germination. Measurement of the plumule and radicle lengths was done on every other day using a meter rule. Fresh and dry weights of radicle and plumule were measured at the end of the experiment using an electronic weighing balance. For dry weight, seedlings were kept in an oven for 48 h at 60°C. Germination reduction caused by weed extract was computed relative to control.

Statistical methods

Data collected were average of three replicates. All data collected were subjected to analysis of variance to test for significant difference among treatments applied, according to Gomez and Gomez (1984) and significant means were separated using New Duncan's Multiple Range Test (NDMRT). Microsoft Excel was used.

RESULTS AND DISCUSSION

Allelochemicals present in the weed extracts

The phytochemical screening of the water extracts of samples of *Chromolaena odorata, Euphorbia heterophylla and Tridax procumbens* is shown in Tables 1 and 2. The results revealed the presence of terpenoid, glycosides, phenols, alkaloids, and flavonoids in the extract of the three weed species used in this study. In contrast, saponin was not found in any of the extracts (Table 1). *E. heterophylla* had significantly highest concentrations of flavonoids (95 mg/l), phenolic acids (81.158 mg/l) and alkaloids (10.57 mg/l). It however contained the significantly lowest concentration of terpenoids (0.346 mg/l) and glycosides (17.552 mg/l) (Table 2). Moreover, *T. procumbens* (41.807 mg/l) and *C. odorata* (38.925 mg/l) had significantly higher concentrations of glycosides than *E. heterophylla*. The concentrations of flavonoids (81.77 mg/l), phenolics (44.323 mg/l) and alkaloids (9.250 mg/l) in *T. procumbens* were not significantly different from the concentrations of the allelochemicals in *C. odorata*. The

Table 1. Different phytochemicals in the root and shoot of extract of *Chromolaena odorata, Euphorbia heterophylla and Tridax procumbens.*

Sample	Flavonoid	Glycosides	Phenolics	Alkaloids	Terpenoids	Saponins
C. odorata	+	+	+	+	+	-
E. heterophylla	+	+	+	+	+	-
T. procumbens	+	+	+	+	+	-

+, indicates the presence of the phtochemical compounds; -Indicates the absence of the phytochemical compounds.

Table 2. Total concentration of phytochemicals in the root and shoot of *Chromolaena odorata, Euphorbia heterophylla and Tridax procumbens.*

Weed extract	Total flavonoid (mg/l)	Total glycosides (mg/l)	Total phenolics (mg/l)	Total Alkaloids (mg/l)	Terpnoids (mg/l)
C. odorata	73.03[b]	38.925[a]	25.840[b]	9.708[b]	0.521[a]
E. heterophylla	95.00[a]	17.552[b]	81.158[a]	10.570[a]	0.346[b]
T. procumbens	81.77[b]	41.807[a]	44.323[b]	9.250[b]	0.416[b]

Values within columns followed by same letter are not significantly different using the standard error (SE).

highest concentration of terpenoids was found in the extract of *C. odorata* (0.521 mg/l) and was significantly higher than those of *E. heteropylla* (0.346 mg/l) and *T. procumbens* (0.416 mg/l) (Table 2).

Effect of the different extracts on germination percentage of the crop tested

Figures 1 and 2 shows the effects of both the root and shoot extracts of the selected weeds on the percentage germination of the test crop (cowpea varieties IT99K-573-1-1 and IT07K-292-10). The trend of inhibition of germination by the extracts of the three selected weeds was the same. However, there was a significant difference observed between the control and all the treated plants. The germination % of variety IT99K-573-1-1 was significantly reduced by aqueous root extracts of *C. odorata,* which produced 85, 60 and 39 germination % at 25, 50 and 75% extract concentrations, respectively. Subsequently, shoot extract of same weed produced 80, 44 and 22 germination % at 25, 50 and 75% extract concentrations, respectively. Similarly, for cowpea IT07K-292-10, root extract of *C. odorata* produced 88, 66 and 38 at 25, 50 germination % and 75% extract concentrations, respectively. While the shoot extracts of the same weed resulted in germination % of 86, 45 and 25 when treated with 25, 50 and 75% extract concentrations, respectively. Germination % for both shoot and root extracts treated varieties were significantly different at 50 and 75 % extract concentrations (Figures 1 and 2). Similarly, root extracts of *E. heterophyllum* at 25, 50 and 75% concentrations produced 76, 64 and 34 germination %, respectively, of cowpea variety IT99K-573-1-1. While the shoot extract of the same weed produced germination % of 70, 50 and 20 at 25, 50 and 75% extract concentration, respectively. Also, germination % of variety IT07K-292-10 followed a similar trend; root extract of *E. heterophyllum* produced a germination % of 84, 61 and 36 at 25, 50 and 75% extract concentrations, respectively. While the shoot extracts of the same weed resulted in germination % of 64, 42 and 18 when treated with 25, 50 and 75% extract concentrations, respectively (Figures 1 and 2). Both the root and shoot extracts of *T. procumbens* affected both cowpea varieties the same way as *E. hetrophyllum and C. odorata*. Aqueous root extracts of *T. procumbens* produced higher germination % at the three extract concentrations for IT99K-573-1-1 than its shoot extract. Similarly for cowpea IT07K-292-10, root extract of the same weed resulted in a lower germination % than the shoot extract in all dilution concentrations. For all the selected weed species, there was a significant difference between the germination % of all cowpea seeds treated with shoot compared to those treated with root extracts at 50 and 75% concentrations, except for *T. procumbens* treatment. Percentage germination of all plants treated with 25% dilution concentration of root extracts was not significantly different from that treated with same dilution concentration of shoot extracts. In summary, inhibition of germination by extracts was concentration dependent, and also was plant-parts specific (Figures 1 and 2).

Shoot extracts of all weed species significantly reduced germination percentage of all the treated cowpea plants

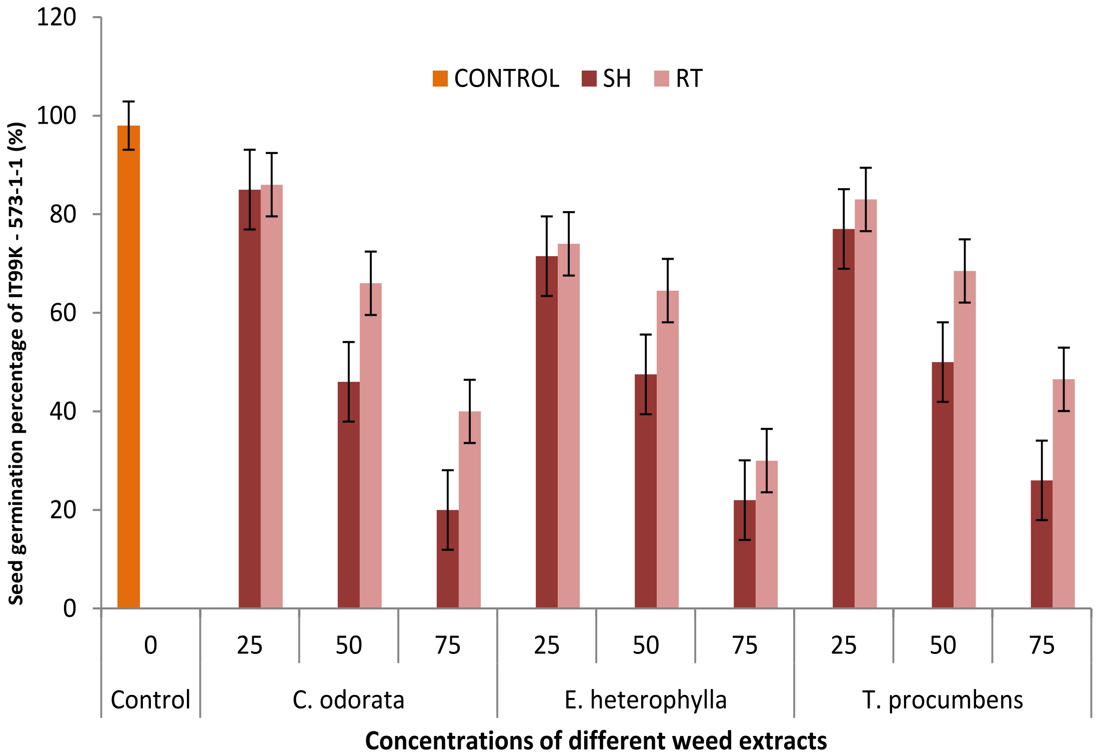

Figure 1. Effects of the extracts of *C.odorata, E. heterophylla* and *T. procumbens* on the percentage germination of the cowpea variety IT99K-573-1-1 under different concentrations of shoot and root extracts. Capped bars indicate standard error bars. SH, Shoot extract; RH,Root extract.

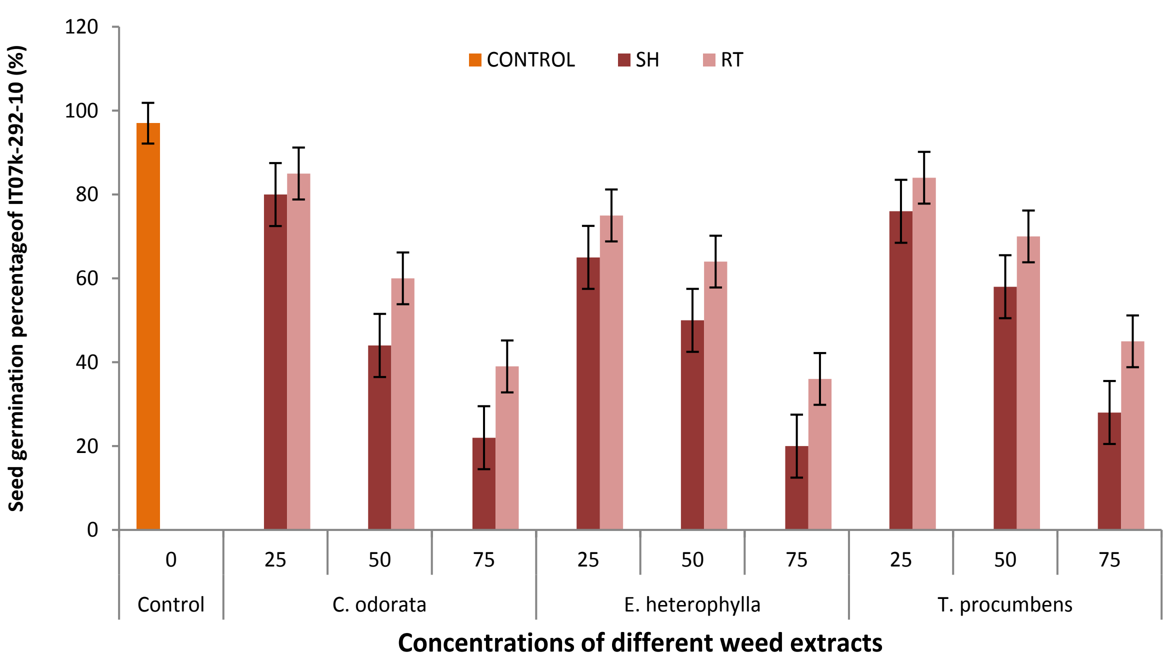

Figure 2. Effects of *C. odorata, E. heterophylla* and *T. procumbens* on the percentage germination of the test crop Variety B: (cowpea variety IT07K-292-10) under different concentrations of shoot and root extracts. Capped bars indicate standard error bars. SH, Shoot extract; RH, Root extract.

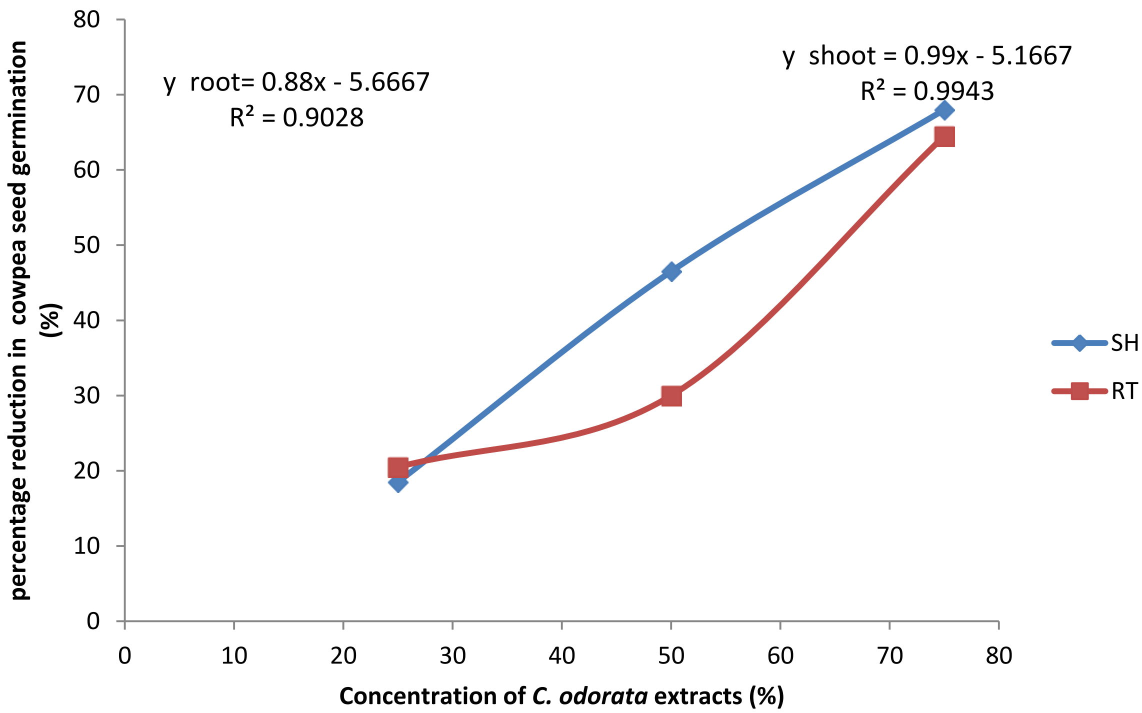

Figure 3. Effect of different extract concentrations of *C. odorata* on percentage reduction in germination of cowpea. Capped bars indicate standard error bars. SH, shoot extract; RH, root extract.

compared to those treated with root extracts. For *C. odorata*, the b-value for the slope of the root extract was 0.88 while that of shoot was 0.99 with very reliable values of coeficient of determination of 90% and 99%, respectively (Figure 3). Similarly, root extract of *E. heterophylla* had a b-value of 0.96 while that of the shoot was 1.2 with coefficient of determination of 99 and 97%, respectively (Figure 4). Also b–value of the root extract of *T. procumbens* was 0.73 and that of shoot extract was 0.76 with coeficient of determination of 99 and 99% respectively (Figure 5). Furthermore, germination inhibition of both cowpea varieties by the selected weed extracts followed the trend: *E. heterophylla* shoot and root extracts significantly inhibited germination followed by extracts of *C. odorata* and *T. procumbens* (Figures 3 to 5).

Effects of the different weed extracts on plumule and radicle lengths

The plumule and radicle lengths of the seedlings of cowpea varieties IT99K-573-1-1 and IT07K-292-10 seedlings in the control were significantly higher than all the other seedlings treated with the extracts of the three selected weeds (Figures 6 and 7) ($P < 0.05$). The control seedling of cowpea varieties had a pooled mean plumule length of 6.6 cm and a mean radicle length of 6.2 cm; while the treated seedlings had a significantly lower plumule length of 3.1 cm and radicle length of 2.9 cm ($P < 0.05$) (Figure 6). The radicle and plumule lengths of cowpea in the control were significantly higher than all the treated plants in both varieties from day five to the end of the experiment; while that of the radicle length was from day six. Seedlings followed the trend of plumule and radicle length increasing with decrease in the concentration of the extracts. Statistical analysis revealed that the extracts had more effect on the radicle length than plumule (Figure 8). Also the degree of inhibition increased with the increase in the concentrations of the extracts.

The process of germination is a crucial stage in plant growth. The extract of the selected weed species significantly retarded the germination of the test crop in this study. The observed inhibition of the seeds of the two cowpea varieties, namely IT99K-573-1-1 and IT07K-292-10 could be attributed to a contribution of allelochemicals present in the extracts of shoot and roots of *C. odorata, E. heterophylla* and *T. procumbens.* Several investigations have shown that the allelochemicals are water-soluble and can accumulate upon release within seeds in direct contact with bioactive concentrations (Winkler et al., 2003; Fara et al., 2014). The result in this study agreed with the findings of Jabeen and Ahmed

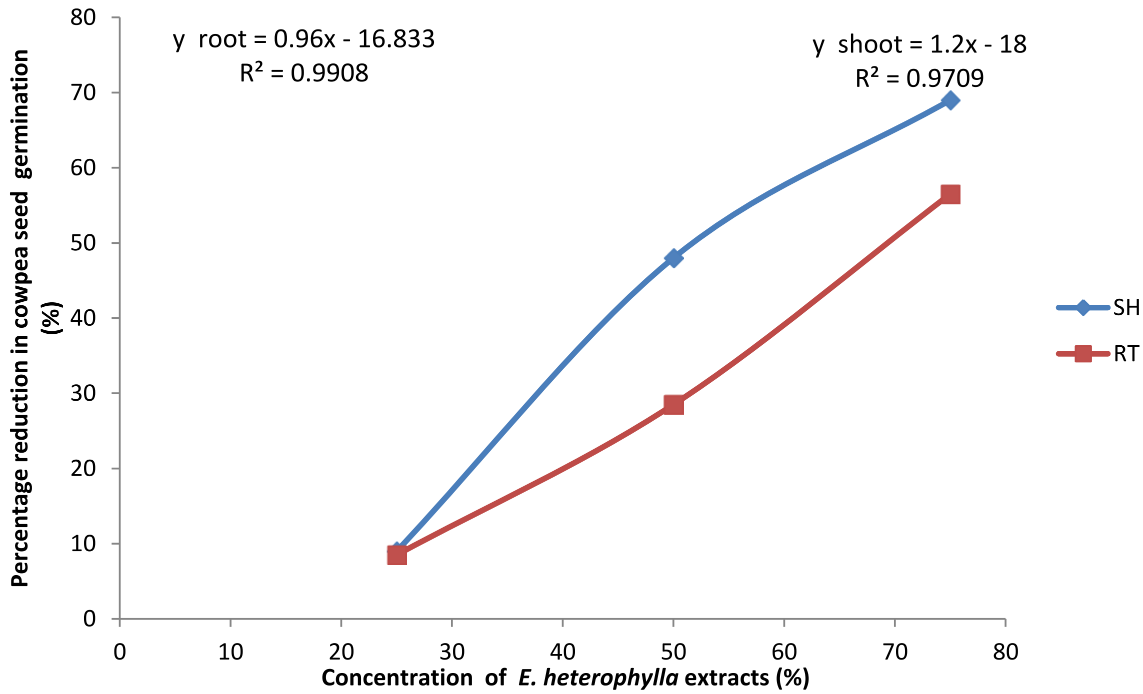

Figure 4. Effect of different extract concentrations of *E. heterophylla* on percentage reduction in germination of cowpea. Capped bars indicate standard error bars. SH, shoot extract; RH, root extract.

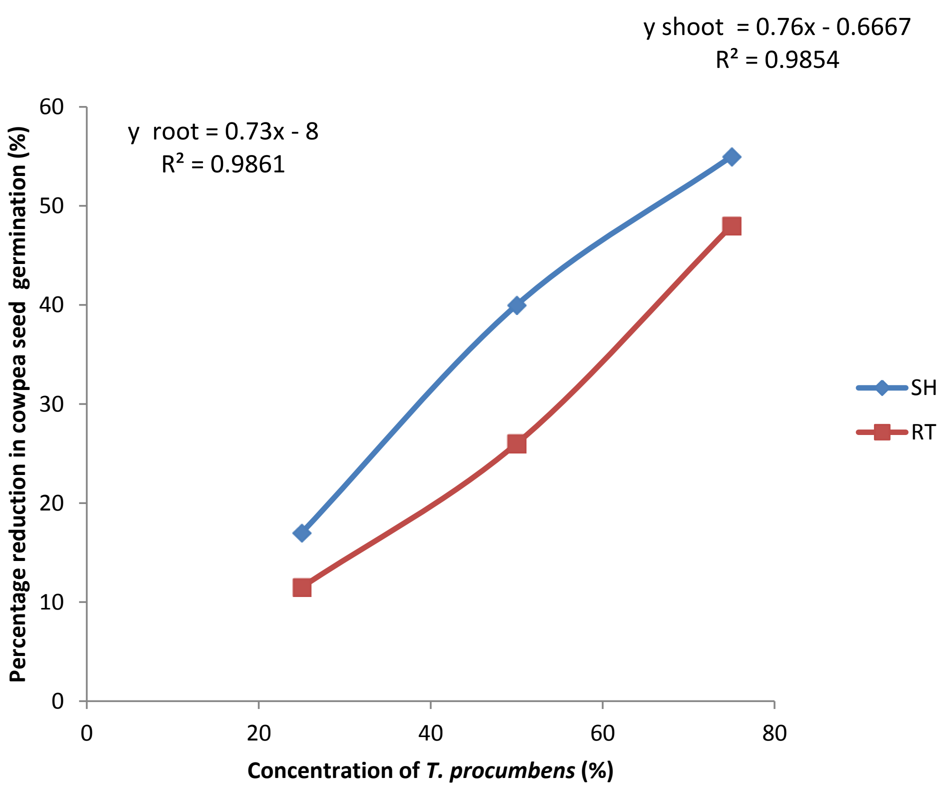

Figure 5. Effect of different extract concentrations of *T. procumbens* on percentage reduction in germination of cowpea. Capped bars indicate standard error bars. SH, shoot extract; RH, root extract.

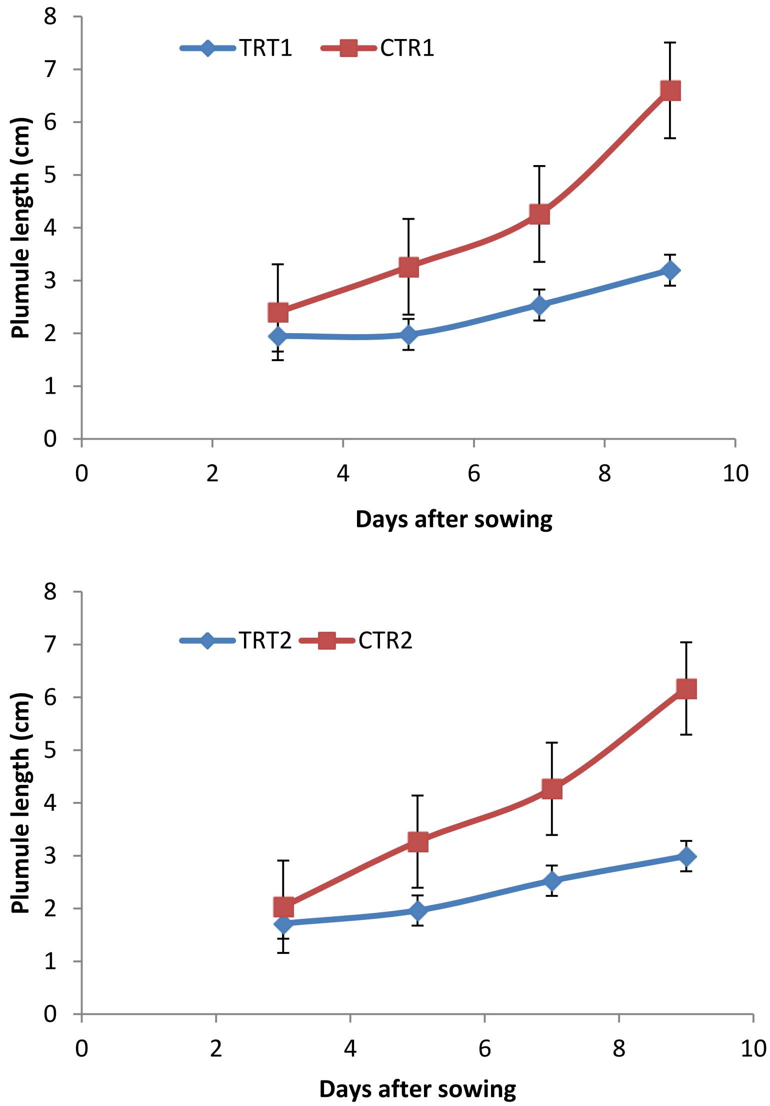

Figure 6. Effect of extracts of the selected weed species on plumule length of the different varieties of cowpea relative to the control (cowpea without extracts application). Capped bars indicate standard error bars. TRT1, Extracts treated variety IT99K-573-1-1; TRT2, Extracts treated variety IT07K-292-10; CTR1, Control for variety IT99K-573-1-1; CTR2, Control for variety IT07K-292-10.

(2009) who observed the effect of *Asphodelus tenuifolius* and *Fumaria indica* on maize seeds and reported inhibition of germination. Moreover, this report is also corroborated by the findings of Oke (1988) that siam weed extract inhibited the germination of seeds of cowpea, soybean and *T*. *procumbens*. Also, Usuah, et al. (2013) reported that both shoot and root extracts of siam weed inhibited the germination of melon, okra, soybean, cowpea and maize. Dabgar and Kumbhar (2010) found that the aqueous extract of *Euphorbia thiamifolia* inhibited seed germination in *Vigna uriculata* and *Vigna radiata*.

The inhibition was also concentration related. The germination percentage of seeds treated with 75% weed extracts was significantly lower than those treated with 50 and 25% extracts, respectively. This finding is similar to the results of Chung and Miller (1995) who found that the degree of inhibition increased with increasing extract concentration. This inhibitory effect on germination of seeds of the species tested in our investigation might be due to allelopathic phytochemicals inhibiting the germination of plants thereby disrupting the cell division, interfering with the mechanism of energy transfer and

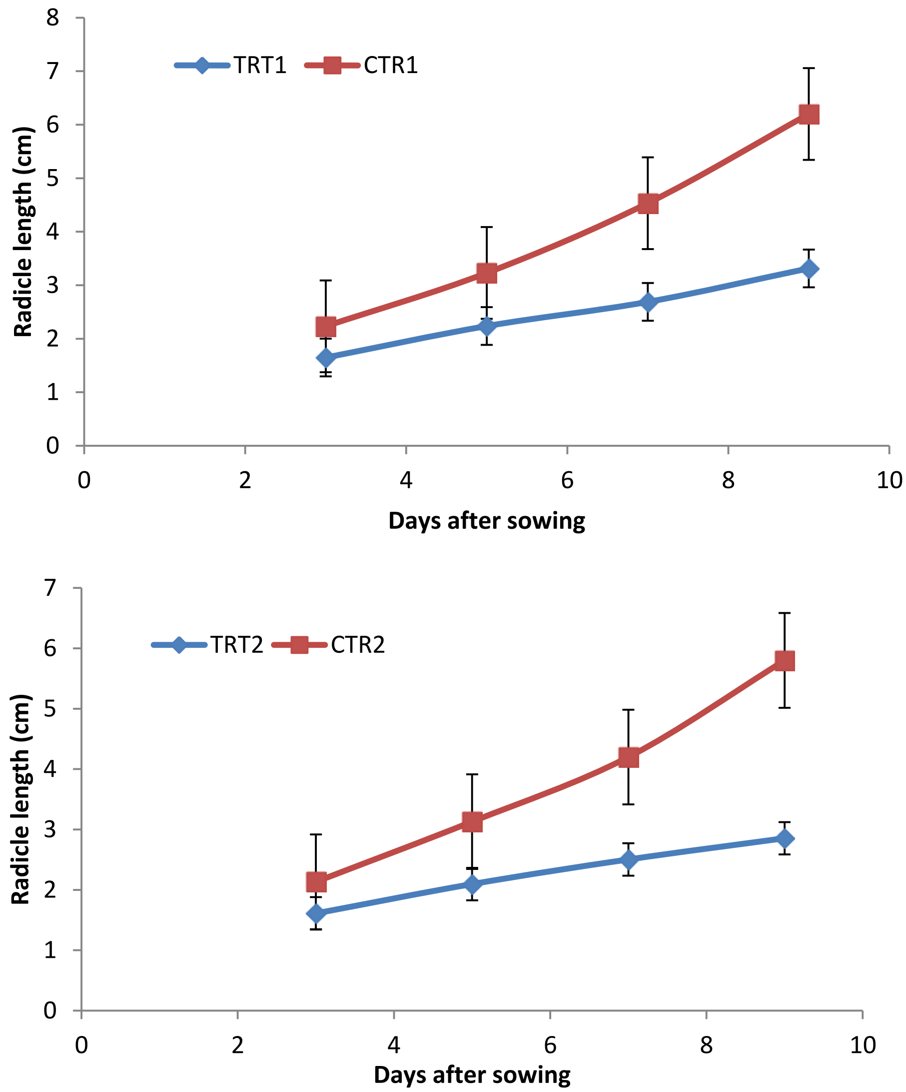

Figure 7. Effect of extracts of the selected weed species on radicle length of the different varieties of cowpea relative to the control (cowpea without extracts application). Capped bars indicate standard error. TRT1, Extracts treated variety IT99K-573-1-1; TRT2, Extracts treated variety IT07K-292-10; CTR1, Control for variety IT99K-573-1-1; CTR2, Control for variety IT07K-292-10.

limiting water and nutrient uptake. Therefore, the inhibitory effect may be due to the entry of water soluble allelochemicals into the seed (Abu-Romman et al., 2010).

In this study, the extracts of the selected weed species significantly inhibited radicle and plumule lengths of the test crop. This is in line with the findings of Kayode and Adanlawo (1997); they revealed that the extracts from leaves of *Gliricidia sepium* had inhibitory effects on the growth of radicle and plumule of cowpea (*Vigna unguiculata*). Allelopathic effect of spurge (*Euphorbia hierosolymitana*) on wheat was studied by Saeid et al. (2010), and they asserted that the extract inhibited both plumule and radicle lengths. Similar result was earlier reported by Kushima et al. (1998) who stated that leachate from melon seeds inhibited the growth of the plumule and the radicle of tomato seedlings. The extracts used in this study had an inhibitory effect on the plumule and radicle length of cowpea varieties IT99K-573-1-1 and IT07K-292-10, which was decreased with increased extract concentration. The results are in agreement with the findings of Jadhar and Goyanar (1992) who noted that the percentage germination, plumule length and radicle length of rice and cowpea decreased with increase in the concentration of *Acacia auriciliformis* leaf

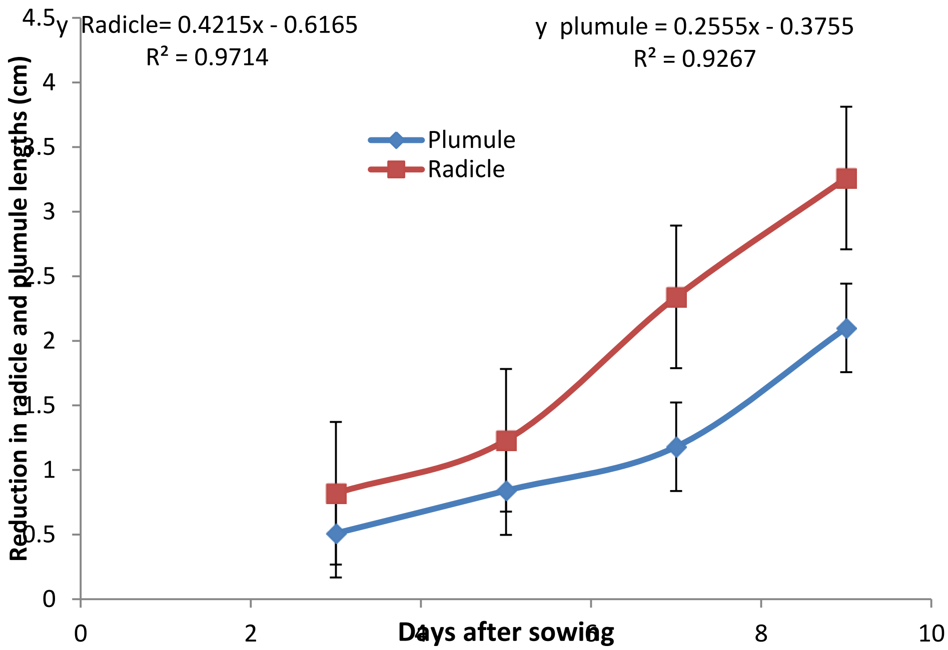

Figure 8. Effect of different extracts of the selected weed species on reduction in plumule and radicle lengths cowpea. Capped bars indicate standard errors.

leachates. Abu-Romman et al. (2010) also reported that the higher concentration of aqueous leachate of *E. hierosolymitana* reduced seed germination, and significantly inhibited the radicle length and growth of wheat seedlings. The reduction in seedling roots length may be attributed to the reduced rate of cell division due to the presence of allelochemicals, which might inhibit gibberellin and indoleacetic acid function (Tomaszewski and Thimann, 1966).

Furthermore, it was revealed that higher concentrations of shoot extracts reduced both the plumule and radicle lengths and was found to be more allelopathic than the root extract. The b-value in this investigation represents the slope of the graph, that is the rate of change in percentage germination due to concentration. The rate of change when shoot extract was used was greater than rate of change when root extract was used. This was collaborated by the findings of Qasem (1995) who reported that shoot extracts were more detrimental than root extracts. In contrast, Rezaie and Yarnia (2009) found both root and shoot extracts to be equally harmful to safflower (*Carthamus tinctorius* L.). The variation in the effect found in this study could be due to difference in phytochemical concentrations in the shoot and root and can be explained by the differences of plant parts in accumulation of phytotoxin (Gonzalez et al., 1997). Also, radicle length was found to be more affected by the extracts than the plumule. This was also consistent with the findings of Friedman (1995), who reported that the allelopathic impact of leachates and extracts are more harmful to the radicle. Alam (1990) also asserted that root growth was more sensitive to the increasing concentration of plant aqueous extracts in comparison to the shoot growth and this could be because the roots were in continuous contact with the extracts.

Conclusion

The water extracts of the selected weed species inhibited seed germination, plumule length, radicle growth, and fresh and dry matter production of cowpea varieties IT99K-573-1-1 and IT07K -292-10. Furthermore, allelopathic effects of weed extracts are weed specific and concentration dependent. Among the different extracts obtained from the weed species, *E. heterophylla* had a more inhibitory effect on cowpea seed germination, plumule and radicle growth compared to *C. odorata* and *T. procumbens.* In the case of weed parts, shoot extracts of the various weed species were more harmful than other root extracts.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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