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Allelopathic effect of *Chromolaena odorata* aqueous leaf extracts on seed germination and seedling growth of selected crop and pasture species in Tanzania

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Abstract
Chromolaena odorata is an invasive weed species adversely affecting both crop and grazing lands in tropical and subtropical areas. This study was designed to investigate the allelopathic effects of *C. odorata* aqueous leaf extract on seed germination and seedling growth of some species. The selected crops include sorghum, white maize, brown and mug beans while pasture species was *Centrosema pubescens* (Centro). *C. odorata* aqueous leaf extract concentrations of 0, 25, 50, 75 and 100% were prepared. The experiment was set under completely randomized design with three replications. Data on seed germination were daily collected while shoot and root length were measured on 10th day of the experiment. Germination percentage (GP), Germination Index (GI), Rate of germination (RG), Inhibitory percentage (IP), Seedling Vigor Index (SVI), relative elongation ratio of root (RERR) and relative elongation ratio of shoot (RERS) were computed. *C. odorata* leaf extract has significant effect ($p < 0.05$) on GP, GI, IP and SVI in all crops and pasture. The GP and GI decreased with increased concentration on selected species. However, the impact was rather low for sorghum, brown beans and Centro. At 100 %, SVI and RERRS for brown beans, mug beans and Centro were 131.35, 36.18, 80.88 and 14.57, 17.87, 75.68 respectively. The SVI, RERR and RERS were highly affected at concentration ≥ 50% while GP, GI and RG were inhibited at 100%. Conclusively, *C. odorata* leaf extract inhibited seed germination and seedling growth of the experimental crop and pasture species. Further investigation on the allelopathic behaviour under field conditions and inhibitory mechanism involved is suggested.

Keywords: *Chromolaena odorat*a, allelopathy, leaf extract, pasture, invasive weed, crops

1. Introduction

The world's most utilized cereal crop and pasture species have been increasingly invaded by weed during the last two centuries (Polley *et al*., 2003) [28]. *Chromolaena odorata* (L.) R. M. King and H. Robinson is among the noxious invasive weed species commonly called Siam weed. Alternative common names include Devil Weed in Western Australia, Kings Weed in South Africa and "*Amachabogho"* in Serengeti district, Tanzania. *C. odorata* also is a shrub which is listed among the most 100 worst invasive species in the world (McFadyen *et al*., 2003; IUCN, 2001) [17, 12]. It grows from 3 m to 7 m high with a taproot which is deep and massive and leaves with pungent odor when crushed. Additionally, propagation of this weed is through seed dispersal while seed germination begins after the rainy seasons where seedlings require sunlight with partial shade to survive (Sahid and Yusoff, 2014) [32]. However, the invasiveness of *C. odorata* to crops and pasture varies with geographical location. This is affirmed by Zachariades *et al*. (1999) [42] who pointed out that Tropical and Sub- tropical areas, Tanzania among them are the most vulnerable areas to *C. odorata* invasions.

In Tanzania, the weed was reported firstly by McFadyen and Skarratt (1996) [18] and lastly by Den Breeÿen *et al*. (2006) [5]. Currently, *C. odorata* is considered as most aggressive weed in Serengeti -Tanzania (Clark and Lotter, 2011; Foxcroft, *et al*., 2013) [3, 8] with fast spreading and likely to invade most parts of our country in few years to come. *C. odorata* grows in a range of habitats including forests, grasslands, cultivated and arid bushlands, as well as in crop and grazing lands. In most cases, *C. odorata* out-competes other species in terms of space and nutrient access causing natural ecosystem degradation and reduced crop and pasture yields and quality. This is because *C. odorata* possesses allelopathic properties that support the production of allelochemicals present in all plant tissues but mainly on leaves (Putnam and Tang, 1986) [27]. However, the amount and composition of allelochemicals for *C. odorata* leaves extracts varies with locality and soil chemical composition (Marinov-Serafimov, 2010) [15] and maturity stages (Fernandez *et al*., 2009) [7].

Therefore, the study intended to investigate the allelopathic effect of *Chromolaena odorata* leaf extracts on seed germination and growth on most dominant and preferred cereal crops and pastures species found in Serengeti district, North Western, Tanzania.

2. Materials and Methods

2.1 Study Site

The samples of *C. odorata* leaves and most preferred and dominant crops and pasture species were collected in Kanyemonta Ward in Serengeti district, North Western Tanzania. The ward is located adjacent to Serengeti National Park that lies between 34 and 36^0 E longitude, and 1 and 2^0 S latitude. The estimate terrain elevation above sea level is 1416 metres, semi-arid climate condition with annual rainfall approximately ranging from 500 mm to 1100 mm. The sampling site vegetation type is grassed woodland.

2.2 Preparation of *Chromolaena odorata* aqueous leaf extract

The collected *C. odorata* leaf samples were analysed at the Animal, Aquaculture and Range Sciences laboratory, Sokoine University of Agriculture, Morogoro, Tanzania. First, the collected *C. odorata* leaves were air dried at room temperature (30ºC ± 4) for seven days and thereafter in an oven at 70 ºC for 48 hr. The dried leaves of *C. odorata* were milled through a 2 mm sieve. A hundred (100) g of powder extracts was added to 1 litre of distilled water in plastic buckets, vigorously stirred and kept for 24 hrs at room temperature and then filtered through double-layered muslin cloth. The filtrates served as a stock solution of 100 % concentration. By subsequent dilution with distilled water leaf extracts of 25, 50 and 75 % concentrations were prepared and stored in conical flasks until required. However, distilled water was used as control (0%) during the experiment.

2.3 Preparation of selected crops and pasture species for laboratory study

The seeds crops that were collected are *Sorghum vulgare* (red variety), *Zea mays* (white), *Phaseolus vulgaris* (brown) and *Vigna radiate* while the pasture was *Centrosema pubescens* (Centro). These seeds were surface sterilized by dipping them into 0.5 % aqueous solution of sodium hypochlorite and rinsed several times with distilled water. Fifteen petri dishes of 10 cm double layered with Whatman Number 1 filter papers per specie per 5 concentrations levels from the leaf extracts was used while control in each species is maintained with distilled water. In each selected species, 10 uniform seeds per specie were sequentially placed in separate petri dishes and watered with 10 ml of each prepared concentration and labelled. The petri dishes were kept in a growth chamber at room temperature (28ºC) until the final germination count. The seeds were considered germinated upon the emergence of the root.

2.4 Experimental design and data collection

The experiment was set in a completely randomized design (CRD) with three replicates. Daily data for seed germination was recorded while the root and shoot lengths were measured 10 days post sowing. Furthermore, computation of seed germination and seedling growth indices was done as described below.

Germination indices

Germination percentage (GP) =

$$\frac{\text{Total number of seed germinated}}{\text{Total number of seed sown}} \times 100 \qquad (1)$$

Germination Index (GI) =

$$\frac{\text{No. of germinated seeds}}{\text{Days of first count}} + \ldots\ldots + \frac{\text{No. of germinated seeds}}{\text{Days of final}} \qquad (2)$$

Rate of germination (RG): was estimated using modified Timpson's index of Khan and Ungar, 1984) [13] by firstly calculating

$$\text{Mean Germination Time (MGT)} = \text{MGT} = \Sigma\ (N \times D)/n. \qquad (3)$$

Where N is the number of seeds which in D-day grow, n is the total number of seeds grown and D is the number of days from the date of germination. The reversing of MGT at the end of this period RG was obtained.

Seedling growth indices

Relative elongation ratio of root (RERR) and shoot (RERS):

$$\text{RER of shoot} = \frac{\text{Mean shoot length of tested plant}}{\text{Mean shoot length of control}} \times 100 \qquad (4)$$

$$\text{RER of root} = \frac{\text{Mean root length of tested plant}}{\text{Mean root length of control}} \times 100 \qquad (5)$$

Inhibitory percentage (IP) =

$$100 - \frac{\%\text{ FG with } C.\ odorata \text{ aqueous leaf extract}}{\%\text{FG without } C.\ odorata \text{ aqueous leaf extract}} \times 100 \qquad (6)$$

Where, FG is final germination percentage.

Seedling Vigor Index (SVI) =

$$\text{Germination \%} \times \text{Root length (cm)} \qquad (7)$$

2.5 Statistical Analysis

The data for germination and seedling growth indices were analyzed with a one-way of variance under GLM using SAS software version 9.4. The means difference of indices measured were tested using Least Significant Difference at 5% confidence limit.

3. Results

3.1 Allelopathic effects of different concentrations of *Chromolaena odorata* aqueous leaf extract on seed germination and seedling growth of selected cereal grain crops

***Sorghum vulgare* (red variety)**

The results for germination and seedling growth indices of *Sorghum vulgare* (red variety) are summarized in Table 1. *Sorghum vulgare* was significantly ($p < 0.05$) affected by *Chromolaena odorata* aqueous leaf extract in all indices except on RG. As concentration increased from 0 to 100%, IP Increased significantly ($p < 0.05$) while GP, GI, SVI, RERR and RERS decreased significantly ($p < 0.05$) and RG did not change ($p > 0.05$). Germination and seedling growth of *Sorghum vulgare* were highly affected at 75% and 100% concentration levels in all parameters except RG remained unchanged in all tested concentrations.

Table 1: Germination and seedling growth indices of *Sorghum vulgare* (red variety)

Conc (%)	GP (%)	GI	RG (day^{-1})	IP (%)	SVI	RERR (%)	RERS (%)
0	100.00^{a}	45.58^{a}	0.20^{a}	0^{d}	600^{a}	100.00^{a}	100.00^{a}
25	100.00^{a}	45.43^{a}	0.21^{a}	0^{d}	585^{b}	100.00^{a}	97.39^{a}
50	96.67^{b}	44.49^{a}	0.22^{a}	3.33^{c}	534^{c}	96.89^{a}	91.69^{a}
75	93.33^{c}	40.23^{b}	0.05^{a}	6.67^{b}	474^{d}	88.32^{ab}	88.44^{a}
100	88.89^{d}	35.35^{c}	0.05^{a}	10.02^{a}	261^{e}	63.25^{b}	83.14^{a}
SEM	0.496	0.762	0.067	0.017	0.10	8.387	8.482
P-value	0.0001	0.0001	0.2011	0.0001	0.0001	0.0001	0.0001

Values in the same column followed by different superscript letters are significantly different at P < 0.05 GP= Germination Percent; GI= Germination Index; RG= Rate of germination; IP= Inhibitory percentage; SVI= Seedling Vigour index; RERR= Relative Elongation Ratio of Root; RERS= Relative Elongation Ratio of Shoot

White maize

The results for germination and seedling growth indices of white maize are in Table 2. Excluding RG and RERS, other measured attributes of white maize were affected significantly ($p < 0.05$) with an increase of the concentration level of *Chromolaena odorata* aqueous leaf extract. IP increased significantly ($p < 0.05$), but GP, GI, SVI and RERR decreased significantly ($p < 0.05$). At 25 % concentration level, germination of white maize was unaffected showing a slightly decrease in GP, RG and GI by 1.11%, 0.15 day^{-1} and 0.74 when related to control. The SVI, RERR and RERS were also slightly reduced by 90. 53, 6.28% and 1.53% compared to control. However, at 100% concentrations levels the inhibitory percentage was highest.

Table 2: Germination and seedling growth indices of White maize

Conc (%)	GP (%)	RG (day-1)	GIIP (%)		SVI	RERR (%)	RERS (%)
0	100.00^{a}	2.47^{a}	9.85^{a}	0.00^{d}	1237.21^{a}	100.00^{a}	100.00^{a}
25	98.89$^{a b}$	2.32^{a}	9.11$^{a b}$	0.00^{d}	1146.68^{b}	93.72^{ab}	98.47^{a}
50	95.56^{b}	2.31^{a}	7.58$^{b c}$	3.30^{c}	706.92^{c}	78.56^{ab}	89.81^{a}
75	91.11^{c}	0.56^{a}	6.03^{c}	6.64^{b}	540.71^{d}	77.76$^{a b}$	85.92^{a}
100	87.78^{c}	0.19^{a}	3.86^{d}	13.34^{a}	461.03^{e}	72.68^{b}	50.21^{a}
SEM	1.314	1.06	0.676	0.024	0.058	8.267	19.555
P-value	0.0001	0.3900	0.0001	0.0001	0.0001	0.0001	0.4196

Values in the same column followed by different superscript letters are significantly different at p < 0.05 GP= Germination Percent; GI= Germination Index; RG = Rate of germination; IP= Inhibitory percentage; SVI = Seedling Vigour index; RERR =Relative Elongation Ratio of Root; RERS =Relative Elongation Ratio of Shoot

3.2 Allelopathic effects of different concentrations of *Chromolaena odorata* aqueous leaf extract on seed germination and seedling growth of selected legume crops

Brown beans

The results for germination and seedling growth indices of brown beans are summarized in Table 3. Germination and seedling growth parameters for brown beans were affected significantly ($p < 0.05$) by *C. odorata* aqueous leaf extract except RG. As concentration increased from low to higher, IP increased significantly ($p < 0.05$) but GP, GI, SVI, RERR and RERS decreased, while RG did not change significantly ($p > 0.05$). Germination parameters were highly affected at 100% leaf extract concentration where GP and GI values were reduced by 22.22 and 10.03 units from the control. Seedling growth parameters were also highly inhibited at 75% and 100% concentration when IP increased up to 23.33 % while SVI, RERR and RERS were tremendously reduced to 131.35, 25.04 and 14.57% respectively. However, nearly all parameters of brown beans were less affected at 25% concentration.

Table 3: Germination and seedling growth indices of brown beans

Conc (%)	GP (%)	GI	RG (day-1	IP (%)	SVI	RERR (%)	RERS (%)
0	98.89^{a}	11.76^{a}	0.84^{a}	0.00^{d}	916.01^{a}	109.94^{a}	100.00^{a}
25	88.89^{b}	10.70^{a}	0.83^{a}	10.01^{c}	786.61^{b}	100.00$^{a b}$	88.82^{a}
50	88.89^{b}	5.44^{b}	0.59^{a}	10.01^{c}	675.61^{c}	86.71$^{a b}$	50.52^{b}
75	83.33^{c}	4.73$^{b c}$	0.27^{a}	16.67^{b}	512.77^{d}	82.40^{b}	39.37^{b}
100	76.67^{d}	1.73^{c}	0.18^{a}	23.33^{a}	131.35^{e}	25.04^{c}	14.57^{c}
SEM	0.860	1.058	0.460	0.005	0.026	7.983	5.803
P-Value	0.0001	0.0001	0.7752	0.0001	0.0001	0.0002	0.0001

Values in the same column followed by different superscript letters are significantly different at p < 0.05 GP= Germination Percent; GI= Germination Index; RG = Rate of germination; IP= Inhibitory percentage; SVI = Seedling Vigour index; RERR= Relative Elongation Ratio of Root; RERS =Relative Elongation Ratio of Shoot

Mug beans

The results for germination and seedling growth indices of mug beans are represented in Table 4. Mug beans were significantly affected by *Chromolaena odorata* leaf extract at ($p < 0.05$) in all germination and seedling growth indices. The increase of concentration from 0 to 100%, increased significantly ($p < 0.05$) the IP to 65.24, but decreased the GP, GI and SVI, RG, RERS and RERR. Mug beans germination indices were highly inhibited at 100% concentration when GP, GI and RG were reduced to 53.89%, 30.47 and 0.27 day^{-1} respectively. Seedling growth indices, (SVI, RERR and RERS) were reduced to 355.64, 57.15% and 82.13% as compared to the control.

Table 4: Germination and seedling growth indices of mug beans

Conc (%)	GP (%)	GI	RG (day^{-1})	IP (%)	SVI	RERR (%)	RERS (%)
0	97.78^{a}	37.92^{a}	0.34^{a}	0.00^{e}	391.82^{a}	104.31^{a}	100.00^{a}
25	91.11^{ab}	37.66^{a}	0.28^{b}	4.45^{d}	370.20^{b}	100.00^{a}	99.7^{a}
50	84.44^{b}	30.93^{a}	0.26^{b}	15.55^{c}	287.89^{c}	87.18^{ab}	92.26^{a}
75	65.56^{c}	28.48^{ab}	0.21^{c}	34.78^{b}	165.94^{d}	70.27^{b}	63.17^{a}
100	43.89^{d}	7.45^{b}	0.07^{d}	65.24^{a}	36.18^{e}	47.16^{c}	17.87^{b}
SEM	4.165	2.738	0.014	0.005	0.031	5.452	12.724
P-Value	0.0001	0.0001	0.0238	0.0001	0.0001	0.0001	0.0044

Values in the same column followed by different superscript letters are significantly different at p < 0.05. GP= Germination Percent; GI= Germination Index; RG = Rate of germination; IP= Inhibitory percentage; SVI = Seedling Vigour index; RERR =Relative Elongation Ratio of Root; RERS =Relative Elongation Ratio of Shoot

3.3 Allelopathic effects for different concentrations of Chromolaena odorata aqueous leaf extract on seed germination and seedling growth in selected pasture legume species

Centrosema pubescens

The results for germination and seedling growth indices of *Centrosema pubescens* as influenced by aqueous leaf extract of *C. odorata* are summarized in Table 5. *Centrosema pubescens* was affected significantly (p < 0.05) by *Chromolaena odorata* in all indices except RG, RERR and RERS. The IP increased significantly (p < 0.05) with increased level of *C. odorata* concentration up to 33.33 % at 100 % concentration. On the other hand, GP, GI, SVI and RERS significantly (p < 0.05) decreased with increased concentration of *C. odorata*. The GP and GI decreased and IP increased significantly (p <0.05) with increase of *C. odorata* concentration. The SVI was rather reduced significantly by increased *C. odorata* concentration although the seedling growth parameters (RG, RERR and RERS) were not significantly (p < 0.05) affected.

Table 5: Germination and seedling growth indices of Centrosema pubescens

Conc (%)	GP (%)	GI	RG (day-1)	IP (%)	SVI	RERR (%)	RERS (%)
0	100.00^{a}	20.38^{a}	0.70 ^{a}	0.00 ^{e}	422.04 ^{a}	108.68 ^{a}	100.00 ^{a}
25	93.33 ^{b}	14.02 ^{b}	0.60 ^{a}	6.67 ^{d}	364.62 ^{b}	100.00 ^{a}	93.67 ^{a}
50	83.33 ^{c}	13.72 ^{b}	0.41 ^{a}	16.67 ^{c}	293.31 ^{c}	86.59 ^{a}	85.65 ^{a}
75	78.89 ^{d}	12.58 ^{b}	0.38 ^{a}	23.33 ^{b}	198.30 ^{d}	84.15 ^{a}	83.05 ^{a}
100	66.11 ^{e}	2.85 ^{c}	0.24 ^{a}	33.33 ^{a}	80.88 ^{e}	40.17 ^{a}	75.68 ^{a}
SEM	1.024	1.294	0.243	0.008	0.014	21.782	10.308
P-Value	0.0001	0.0001	0.6190	0.0001	0.0001	0.2818	0.5301

Values in the same column followed by different superscript letters are significantly different at p < 0.05. GP= Germination Percent; GI= Germination Index; RG = Rate of germination; IP= Inhibitory percentage; SVI = Seedling Vigour index; RERR =Relative Elongation Ratio of Root; RERS =Relative Elongation Ratio of Shoot

4. Discussion

4.1 Allelopathic effects of different concentrations of *Chromolaena odorata* aqueous leaf extract on seed germination and seedling growth of selected cereal crops

***Sorghum vulgare* (red variety)**

Germination of *sorghum vulgare* was affected significantly by *Chromolaena odorata* leaf extract in all indices except on rate of germination (RG) as shown in Table 1. Results from the study carried by Mohammed *et al*. (2012)[19] on the effect of leaf extract from selected allelopathic plants on germination and seedling growth of *Sorghum bicolor* L. set under similar concentration levels support the results of the current study that, germination percentage (GP) decrease with increased concentration levels of allelopathic leaf extract. However, contrasting results were from Mubarak *et al*. (2009) [21] and Phiri (2010) [27] who reported that, GP of sorghum was not significantly affected by *Moringa oleifera*, *Khaya senegalensis* and *Albizia lebek*. The difference in germination exhibited at highest concentration may be due to the difference in crop varieties which may show selective permeability of seed coat to the inhibitory substances. The GI for sorghum was reduced as the concentration increased which was in agreement with Ramamoorthy and Paliwal [30].The RG for sorghum seeds was not affected by *C. odorata* leaf extract but decreased insignificantly with concentration levels. This might be due to weed inability to obstruct seed imbibition. Conversely, opposite results were reported by Mohammed *et al*. (2012) [19] where RG increased with concentration. However, in their study greater inhibition of RG was only at 100% concentration while under this study it was from 75%.

Seedling growth indices for *Sorghum vulgare* were significantly affected by *Chromolaena odorata.* Comparable results on seedling growth effect due to *C. odorata* leaf extract were reported for *Sorghum bicolor* (Onwugbuta-Enyi, 2001) [26]. However, IP increased while (SVI), RERR and RERS decreased as the concentration level increased in the present study. Similar results were recorded when sorghum was tested with *Trianthema portulacastrum* Randhawa *et al*., 2002) [31], *Ammi majus, Guiera senegalensis and Salix species* (Mohammed *et al*., 2012) [18]. Randhawa *et al*., 2002) [31] claimed that *Sorghum vulgare* was highly inhibited at higher concentration (75 and 100%) as was the case for the present study. This indicates substantial *C. odorata* leaves inhibitory (allelopathic) effect for the seedling growth of *Sorghum vulgare* seeds. However, Ramamoorthy and Paliwal [30] reported that root length was inhibited at ≥ 50% concentration while shoot length was inhibited at ≥ 75% concentration levels. The decrease in root length compared to shoot length at higher concentrations could be due to high level of root inhibiting allelochemicals substances.

White maize

Germination parameters for white maize were significantly inhibited by *Chromolaena odorata* leaf extract in all indices excluding the rate of germination (RG) as shown in Table 2. These results are in agreement with those obtained by Devi and Dutta (2012) [6] and Usuah *et al*. (2013) [41]. In contrary, Musyimi *et al*. (2012) [22] reported that, germination percentage (GP) and GI of maize seed were not significantly affected by *Tithonia diversifolia* leaf extract across tested concentrations. The reason might be due to the difference in allelochemicals compounds present between the weeds. In comparison to control, GP, RG and GI for white maize were highly inhibited at highest concentration to 87.78%, 0.19 day^{-1} and 3.86 respectively. However, the study assaying the allelopathic effect of *Parthenium* plant on maize by Khan *et* *al*. (2011) [14] showed lower GP and GI (34.2% and 2.85) and higher RG (0.24 day^{-1}) over present study. Germination indices at 25% concentration were almost unaffected with a slightly decrease in GP, RG and GI by 1.11%, 0.15 day^{-1} and 0.74, respectively as compared to the control. This might be due to the low amount of allelochemicals substance that might not inhibit germination metabolic activities of white maize as the concentration decreased.

The seedling growth parameters of white maize were also significantly affected by *C. odorata* leaf extract in all indices except on relative elongation ratio of root (RERR). As the concentration increased, inhibitory percentage (IP) increased from above 25% concentration which is contrary to the results of Devi and Dutta (2012) [6], Suwal *et al*. (2010) [38] and Gill *et al*. [9] where inhibition increased above 0%. At 75 % and 100% concentrations, SVI, RERR and RERS were highly reduced. These findings do agree with those reported by Zohaib *et al*. (2014) [44] who studied the effect of *Parthenium* weed on maize. Furthermore, inhibition by *C. odorata* was higher for RERR than RERS which was also reported by Masum *et al*. (2012) [16], Devi and Dutta (2012) [6] and Nishida *et al*. (2005) [24], also reported that root tissue has greater permeability to allelochemicals released from *C. odorata* leaf extract than shoot.

4.2 Allelopathic effects of different concentrations of *Chromolaena odorata* aqueous leaf extract on seed germination and seedling growth of selected legume crops.

Brown beans

Germination and seedling growth parameters for brown beans were almost affected significantly by *Chromolaena odorata* leaf extract as shown in Table 3. Germination indicators of brown beans were highly affected at 100% concentration which was also supported by Shikha and Jha (2015 [36]. Germination percentage (GP) and germination index (GI) were reduced to 22.22% and 10.03% while RG change was insignificant. Contrary results were reported by Treber *et al*. (2015) [40] when they assessed the allelopathic effect of *Pale Persicaria* on two soybean cultivars at 1, 5 and 10% concentration levels. Their results pointed out that, highest GP reduction was at 5% but on average, germination of soybean was not significantly affected by leaf extracts. Similar results on inhibition of GI with increased concentration were reported by Shikha and Jha (2015) [36] while RG was not in agreement with the finding of Masum *et al*. (2013) [16] who investigated the allelopathic effect of *Parthenium* on soybean and haricot bean.

Seedling growth parameters were highly inhibited at 75% and 100% concentration in the study. The inhibitory percentage (IP) increased from 16.67% and 23.33 % while seedling vigour index (SVI), relative elongation ratio of root (RERR) and relative elongation of shoot (RERS) were reduced to 403.24 and 784.66, 27.54% and 84.9% and 60.63% and 85.43%, respectively relative to the control. However, Netsere and Mendesil (2011) [23] and Masum *et al*. (2013) [16] showed that the highest inhibition was only at 100% concentration. RERR and RERS were not only inhibited and decreased to 37.67% and 98.34% but also SVI was reduced to 55.54 Compared to the control under the study examining the allelopathic activity of *Parthenium hysteropharus* l. leaf extract on *Pisum sativum* (Shikha and Jha, 2015) [33]. This was also supported by Cruz- Ortega *et al*. (2004) [4] when determining allelopathic effect of *Lantana camara* aqueous leaf extract on bean who revealed that, *L. camara* induced the greatest inhibition in bean RERR (41%). However, brown beans growth indicators were less affected at 25% concentration. This was also similar to other findings elsewhere (Netsere and Mendesil, 2011; Tahseen *et al*., 2015) [23, 16]. Germination of brown beans was highly affected at 100% while seedling growth indicators were affected at 75% and 100%. Nevertheless, at 25% concentration the crop had good seed germination and growth.

Mug beans

Mug beans were significantly affected by *Chromolaena odorata* leaf extracts in all germination and seedling growth indices as shown in Table 4. These results were in agreement with those reported by Moosavi *et al*. (2011) [20] in their study which investigated the allelopathic effect of sorghum extract on germination and seedling growth of mug beans. Their results revealed that, allelopathic effect of different concentrations decreased significantly with increase in concentration levels. In the present study, indices for mug beans germination were highly inhibited at highest concentration (100%). It was stated that, germination indices are highly inhibited at higher concentration of weed extract due to an increase in allelochemicals concentration from phenolic acids compounds (Sanchez-Moreiras *et al*., 2004) [35]. The crops under *Asteraceae* family, are reported to contain allelochemicals with high amount of hydroxamic (Zeng *et al*., 2008) [43], which might affect its germination and other plants through synthesizing either the shikimic acid or acetate pathways (Rizvi and Rizvi, 1992; Olofsdotter *et al*., 1995) [32, 25]. This allelochemical might also be present in mug beans that affected its germination by reducing its GP, GI and RG to 53.89%, 30.47 and 0.27 day^{-1} respectively compared to control.

In this study, it was noted that at 100% concentration of *C. odorata* aqueous leaf extract the IP increased to 65.24 while SVI, RERR and RERS were reduced to 355.64, 57.15% and 82.13% respectively compared to control. Channappagoudar *et al*. (2003) [2] also reported that the seedling vigour index of soybean was highly decreased due to allelopathic effect of sunflower at higher concentration. On the other hand, Khan *et al*., (2011) [14] reported that, *Parthenium* weed highly reduced the shoot and root length and root weight of soybean (*Glycine max* L.) and mug bean (*Vigna radiata* L.) when the concentrations were higher. However, mug bean root length was reduced more than the shoot. This may be due to high presence of ferric acid (FA) after 72 hrs from *C. odorata* leaves causing a reduction in the contents of water-soluble proteins and endogenous total phenolic, whereas the activities of proteases, peroxidases and polyphenol peroxidases of mug beans increases reducing cell division and root elongation causing late root growth(Singh *et al*., 2014) [37].

4.3 Allelopathic effects for different concentrations of *Chromolaena odorata* leaf extract on seed germination and growth in selected pasture legume species

Centrosema pubescens

The maximum allelopathic effect of *C. odorata* on germination percentage (GP) and germination index (GI) for *Centrosema pubescens* seeds were exhibited at 100% concentration and this was in agreement to the findings of Rusdy *et al*. (2015) [33]. This may be due to high amount of allelochemicals present on *C. odorata* leaf extract as noted elsewhere (Suwal *et al*., 2010; Devi and Dutta, 2012; Sahid and Yusoff, 2014) [38, 6 and 34]. This resulted to the reduced GP, GI and the rate of germination (RG) to 33.89%, 17.53 and 0.46 sequentially compared to controls.

Seedling growth of *Centrosema pubescens* seeds was also affected by *Chromolaena odorata* leaf extract. Ilori *et al*. (2010 [10] and Ambika and Poornima (2004) [1] claimed that, *C. odorata* leaf extract stimulated the seedling growth of *Celosia argentea* and soybean. This might be due to presence of inhibitory allelochemicals compounds found in *C. odorata* that was revealed in other studies on various crop and pasture species (Rusdy *et al*., 2015; Devi and Dutta, 2012; Sahid and Yusoff, 2014) [33, 6, and 34]. *C. odorata* had high allelopathic effect on seedling growth than *Parthenium hysterophorus* (Masum *et al*., 2012) [16]. This varied response occurs because of higher concentration and the selectivity of allelochemicals on the target plants (Inderjit and Duke, 2003) [11]. However, *C. odorata* had lower allelopathic effect than *Cyperus esculentus* and *Panicum maximum* extracts (Usuah *et al*., 2013) [41]. Among seedling growth parameters, inhibitory percentage (IP) and seedling vigour index (SVI) were affected significantly by *C. odorata* leaf extract which is in agreement with Rusdy *et al*. (2015) [33]. However, the relative elongation ratio of root (RERR) and relative elongation ratio of shoot (RERS) were significantly unaffected as concentration of *C. odorata* increased. This may be due to the presence of allelochemicals compounds which inhibit production of auxin and gibberellins hormones. The highest inhibition of seedling growth of *C. pubescens* was exhibited at highest concentration of *C. odorata* leaf extract. This resulted to an increased IP to 33.33 % while SVI decreased to 341.52 as the concentration increased as compared to the control.

5. Conclusion

The results of this study are in agreement with the null hypothesis which stated that *C. odorata* aqueous leaf extract has significant effect on seed germination and seedling growth of the selected cereal crops and pasture species. The seedling growth for the selected species in the study was more inhibited by *C. odorata* aqueous leaf extract than their germination. High inhibition of germination and seedling growth was highly pronounced at 75 and 100% concentration levels. Thus areas with high infestation of the weed covering are advised to reduce or remove the weed by advised methods to less than 70 % cover. Despite *C. odorata* leaf extract revealed to affect selected cereal and pastures crops, but yellow maize and finger millet exhibited better performance among the cereal crops, white maize, brown beans among legumes crops and *Centrosema pubescens* in selected pasture legume species. Further investigation is needed on the allelopathic behavior under field conditions and inhibitory mechanism involved.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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