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Phytotoxic effects of *Euphorbia dracunculoides:* a weed of rainfed chickpea-chickpea cropping system

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Abstract

Phytotoxic effect occurs when plants release chemicals that inhibit neighoubouring plants. Phytotoxic effects of aqueous extracts of different parts of *Euphorbia dracunculoides* L. *(*green spurge) at two concentrations, and its infested soil were investigated on germination and seedling growth of chickpea (*Cicer arietinum* L.). The fruit extract at 1:20 (w/v) concentration caused maximum reduction (12%) in germination of chickpea seeds while leaf extract at 1:10 (w/v) concentration resulted in maximum mean germination time value and minimum germination index of chickpea seeds. All the traits of chickpea seedling growth including emergence were adversely affected by the aqueous extracts at both concentrations. Further, the inhibition of chickpea seedling growth was more pronounced with 1:10 (w/v) concentration whereas the lower concentration (1:20 w/v) showed stimulatory effect on shoot length, seedling vigor index and chlorophyll contents of chickpea seedlings. The leaf extract at 1:10 (w/v) concentration proved most harmful to seedling growth and chlorophyll contents (76% reduction) of chickpea. Soil beneath the *E. dracunculoides* plants significantly reduced emergence (23%), seedling vigor index (55%) and chlorophyll content (19%) of chickpea but a significant increase in N (6%), P (16%) and K (4%) contents of chickpea seedlings was recorded. Thus it can be concluded that *E. dracunculoides* contains compounds in its tissues which may cause phytotoxic effects on chickpea under field conditions.

Additional key words: *Cicer arietinum;* emergence; germination; green spurge*;* phytotoxicity; seedling growth.

Resumen

Efectos fitotóxicos de *Euphorbia dracunculoides,* una mala hierba del sistema de cultivo garbanzo-garbanzo de secano

Se produce un efecto fitotóxico cuando las plantas liberan sustancias químicas que producen inhibiciones en las plantas próximas. Utilizando extractos acuosos a dos diferentes concentraciones de distintas partes de *Euphorbia dracunculoides* L., así como del suelo infestado, se investigaron sus efectos fitotóxicos sobre la germinación y crecimiento de plántulas de garbanzo (*Cicer arietinum* L.). Extractos del fruto 1:20 (p/v) provocaron la máxima reducción (12%) en la germinación de las semillas de garbanzo, mientras que extractos de hoja 1:10 dieron el máximo valor del tiempo medio de germinación y el mínimo en el índice de germinación. Todos los caracteres de crecimiento de las plántulas de garbanzo, incluyendo la emergencia, fueron perjudicados por los extractos acuosos a ambas concentraciones. Además, la concentración 1:10 inhibió el crecimiento de las plántulas de garbanzo de forma más pronunciada, mientras que la 1:20 mostró un efecto estimulante sobre la longitud de brotes y el índice de vigor y contenido de clorofila de las plántulas de garbanzo. El extracto de hoja 1:10 resultó más perjudicial para el crecimiento de plántulas y el contenido de clorofila (76% de reducción). Suelo extraído debajo de las plantas de *E. dracunculoides* redujo significativamente la emergencia (23%), el índice de vigor (55%) y el contenido de clorofila (19%) de las plántulas, pero en cambio se registró un aumento significativo en el contenido en N (6%), P (16%) y K (4%) de las plántulas. Se concluye que *E. dracunculoides* contiene compuestos en los tejidos que pueden causar efectos fitotóxicos en garbanzo en condiciones de campo.

Palabras clave adicionales: *Cicer arietinum;* crecimiento de las plántulas; emergencia; fitotoxicidad; germinación.

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Introduction

Allelopathy interactions are based primarily on the production of secondary chemicals by the plants that produce a wide array of biochemical compounds affecting the growth and development of plants grown in the neighborhood (Shaukat *et al*., 2003; Macias *et al*., 2004). The chemicals involved in allelopathic interactions are present in virtually all plant parts and in most tissues including leaves, stems, fruits, roots, rhizomes, buds and seeds (Weston and Duke, 2003; Narwal, 2004). Different weed species differ widely in their ability to produce allelopathic effects (Hamayun *et al*., 2005). Different parts of same weed also differ in their ability to produce allelopathic effects so that some parts exhibit more suppressive activity against germination or growth than others (Tanveer *et al*., 2008). A number of studies have shown that residues from several weed species release phytotoxins into the soil, thus affecting the growth of crop plants (Batish *et al.,* 2007a,b).

Chickpea (*Cicer arietinum* L.) is a dry pulse crop of the family Fabaceae and is one of the important conventional crop in rainfed chickpea-chickpea cropping system of Pakistan. Being drought tolerant, 70% of the rainfed agriculture is occupied by this crop. The chickpea yield is lower in Pakistan as compared to maximum potential of cultivars. One of the limiting factors of high yield is presence of weeds in field. In Pakistan, weeds reduce the yield by 24-63% in chickpea (Tanveer *et al*., 1998) because of slow growth rate and limited leaf area development at early stages of crop growth and establishment (Solh and Pala, 1990).

Euphorbia dracunculoides L. (Green Spurge: family Euphorbiaceae) is a much branched annual winter weed. In Pakistan it is grown in October-November in rainfed (less than 200 mm yr^{-1}) areas of chickpea-chickpea cropping system and matures in April. Other species *of Euphorbia,* namely *E. helioscopia, E. hirta* and *E. granulata* have also been reported in Pakistan. World over there is no published data on *E. dracunculoides* being phytotoxic, although several other species of *Euphorbia* have been demonstrated to be phytotoxic (Alsaadawi *et al*., 1990; Tanveer *et al*., 2010). Thus the present study was undertaken to determine the phytotoxic effect of *E. dracunculoides* on the germination and seedling growth of chickpea crop which was found to be frequently infested by this weed.

Material and methods

Seven months old plants of *E. dracunculoides* were uprooted at maturity in May 2008 and dried at room temperature for one week. Average dry weight was 18 g $plant^{-1}$. Plant parts *i.e.* roots, stems, leaves and fruits were separated and small pieces were made with a scissor. Dried plant parts as well as whole plants were immersed in tap water separately in the ratio of 1:10 and 1:20 (w/v) at room temperature for 24 hours. The aqueous extracts of each were obtained by filtering water through sieve and then through Minisart© non-pyrogenic, 0.45 µm filters. The pH, osmotic potential and electrical conductivity of these extracts ranged from 8.26 to 9.07, –0.48 to –0.78 MPa and 3.08 to 9.45 ms m^{-1}, respectively.

Two experiments were carried out with whole plant, stem, leaf, fruit and root extracts of *E. dracunculoides* using distilled water as a control in the laboratory. A third experiment was conducted with soil collected from *E. dracunculoides* infested field and an adjacent field without this weed. In experiments I, II treatments were arranged in a completely randomized design (CRD) with factorial arrangement in 9 cm diameter Petri dishes. Experiment III was done in CRD. There were four replications in each experiment.

Experiment I: Phytotoxic effects of aqueous extracts of different parts of *E. dracunculoides* on germination of chickpea

In this experiment 25 seeds of chickpea were placed on filter papers in Petri dishes, and 5 mL distilled water or plant extract was added to each Petri dish according to the treatment and concentration at the start of the experiment. The Petri dishes were placed at an average room temperature of 20.5°C. Extract or water was added according to need during the course of experiment. The experiment was repeated twice.

Germination was determined by counting and removing germinated seeds daily upto 10 days. Seeds were considered germinated when radical length was

Abbreviations used: CRD (completely randomized design), GI (germination index), MGT (mean germination time), SVI (seedling vigour index).

over 2 mm. Germination was observed daily according to AOSA (1990). Mean germination time (MGT) was calculated as per equation of Ellis and Roberts (1981):

$$MGT = \frac{\sum(D_n)}{\sum n}$$

where *n* is the number of seeds that had germinated on day *D*, and *D* is the number of days counted from the beginning of germination. The germination index (GI) was calculated as per AOSA (1983) by using the following formula:

$$GI = \frac{\text{No. of germinated seeds}}{\text{Days of firts count}} + \ldots + \frac{\text{No. of germinated seeds}}{\text{Days of final count}}$$

Seedling vigour index (SVI) was calculated according to Abdul-baki and Anderson (1973) as:

$$SVI = \text{Germination } \% \times \text{Radical length (cm)}$$

Experiment II: Phytotoxic effects of aqueous extracts of different parts of *E. dracunculoides* on seedling growth of chickpea

In this experiment ten seeds of chickpea were sown in sand filled Petri dishes, and 12 mL of extract or distilled water was added in Petri dishes according to the treatment and concentration. Petri dishes were placed at an average room temperature of 19°C for 15 days. During this period Petri dishes were observed daily and distilled water or extract was added in each Petri dish according to requirement. After 15 days seedlings were up rooted and washed with water. The length of roots and shoots was measured. One gram of fresh leaves was collected from each replication and leaf area was measured using leaf area meter. Roots and shoots were dried in an oven at 70°C till constant weight was obtained.

Experiment III: Phytotoxic effects of *E. dracunculoides* infested soil on seedling growth of chickpea

Soil was collected to a depth of 10 cm from plot where *E. dracunculoides* had been growing for the last three years (test) and also from fields free of this weed (control). Soil was dried at room temperature and sieved through 2 mm mesh. Ten grams of test and same amount of control soil was uniformly spread in 9 cm diameter Petri dishes, separately. Ten seeds of chickpea were placed uniformly on soil. Seeds were covered with the same soil as spread underneath. Soil was adequately moistened with distilled water. Petri dishes were placed at an average room temperature of 19°C for 15 days. During this period Petri dishes were observed daily and equal amount of water was added in each Petri dish according to requirement. After 15 days seedlings were up rooted and washed with water. The length of roots and shoots was measured. Roots and shoots were dried in an oven at 70°C till constant weight was obtained.

A modified protocol (Arnon, 1949; Mochizuki *et al*., 2001) was used to measure chlorophyll content. Fresh leaves of chickpea weighing 300 g were collected from each replication and grinded with a pestle and mortar. The powder was transferred to a Falcon tube and 20 mL of 80% acetone was added and thoroughly mixed. The absorbance (A) of chlorophyll content was measured at wavelengths of 645 and 663 nm using a spectrophotometer. The total chlorophyll concentration was calculated as follows:

$$\text{Total chlorophyll (mg g}^{-1}) = [(8.02 \times A663) + (20.20 \times A645)] \times V/1{,}000 \times W$$

where V = volume of the extract (mL); W = weight of fresh leaves (g).

NPK concentration in seedlings (%)

Dried ground material (0.1 g) was placed in digestion tubes, 2 mL of conc. H_2SO_4 and 1 mL of 35% hydrogen peroxide was added and incubated over night at room temperature. Then 1 mL of H_2O_2 (35%) was poured and heated up to 350°C in digestion block until fumes were produced and continued to heat for another 30 min. Digestion tubes were removed from the block and cooled. Then 1 mL of H_2O_2 was slowly added and tubes were placed back into the digestion block until fumes were produced for 20 min and material became colorless. The volume of extracts was made up to 50 mL with distilled water. Then it was filtered and used for determination of mineral elements (Wolf, 1982).

Potassium was determined with flame photometer. A graded series of standards (ranging from 2 to 12 mg L^{-1}) of KCl was prepared and standard curve was drawn. The values of K from flame photometer were compared with standard curve and total quantities were computed.

The extracted material (5 mL) was mixed in 10 mL of Barton reagents and total volume was made as 50 mL. The samples were kept for half an hour and P contents were determined by spectrophotometer using standard curve. The Barton reagent was prepared as

described by Ashraf *et al*. (1992): Solution A, 25 g of ammonium molybdate was dissolved in 400 mL of distilled water; Solution B, 1.25 g of ammonium metavenadate was dissolved in 300 mL of boiling water, then cooled and 250 mL of conc. HNO_3 was added and again cooled. Solution A and B were mixed and volume was made up to one liter.

For N determination, 5 mL of aliquot was taken in Kjeldhal flask and it was placed on the Kjeldhal ammonium distillation unit, 10 mL of 40% sodium hydroxide solution was added and the flask was immediately connected to the distillation apparatus. Five mL of 2% boric acid solution was taken and few drops of mixed indicator (bromocresol green + methylene red) in 100 mL conical flask. When the distillate was approximately 40-50 mL, the conical flask was removed and distillation was turned off. The distillate was cooled for few minutes and titrated with 0.01 N standard sulphuric acid (90% H_2SO_4) up to pink end point.

Statistical analysis

The data collected were analyzed statistically using Fisher's analysis of variances technique and treatment means showing F-values significant were compared using least significant difference (LSD) at 0.05 probability level (Steel *et al*., 1997).

Results

Experiment I

It is evident form data (Table 1) that *E. dracunculoides* extracts significantly influenced germination percentage, MGT and GI of chickpea seeds. The lowest germination (80.50%) was recorded in seeds treated with fruit extract and it was statistically similar to all other extracts except distilled water (control). A considerable reduction of 6-8% was noted with the application of different *E. dracunculoides* extracts over control. The highest germination (91%) was recorded in control which was statistically at par with whole plant extract. The statistically maximum MGT value was observed in leaf extract followed by whole plant and stem extracts as against the minimum MGT recorded in control. When chickpea seeds were exposed to leaf, stem, whole plant, fruit and root extracts, MGT was increased by 46, 29, 29, 22 and 18% over distilled water (control), respectively. The lowest GI was recorded in seeds subjected to leaf extract. Germination

Table 1. Phytotoxic effect of aqueous extracts of *E. dracunculoides* on germination of chickpea. Means sharing the same letter in a column did not differ significantly at 5% probability level. Figures in parenthesis show % increase (+) or decrease (–) over control

Extract	Germination (%)			Mean germination time (days)			Germination index		
	1:10	1:20	Mean	1:10	1:20	Mean	1:10	1:20	Mean
Distilled water (Control)	91^{a}	91^{a}	91.00^{a}	3.12^{g}	3.12^{g}	3.12^{e}	8.16^{a}	8.16^{a}	8.16^{a}
Whole plant extract	81de (–11)	90^{a} (–1)	85.50^{b} (–6)	4.27^{b} (+36)	3.77^{e} (+21)	4.02^{b} (+29)	5.44^{f} (–33)	6.79^{c} (–17)	6.11^{c} (–25)
Stem extract	83^{c-e} (–9)	86^{a-d} (–5)	84.50^{b} (–7)	4.21^{bc} (+34)	3.84^{e} (+23)	4.02^{b} (+29)	5.58^{f} (–32)	6.59^{c} (–19)	6.09^{c} (–25)
Leaf extract	84^{b-e} (–8)	84^{b-e} (–8)	84.00^{b} (–8)	5.09^{a} (+63)	4.04^{cd} (+29)	4.56^{a} (+46)	4.42^{g} (–46)	5.61^{f} (–31)	5.01^{d} (–39)
Fruit extract	87^{a-c} (–4)	80e (–12)	83.50^{b} (–8)	3.89^{de} (+25)	3.75^{e} (+20)	3.82^{c} (+22)	6.19^{d} (–24)	6.31^{d} (–23)	6.26^{c} (–23)
Root extract	82^{c-e} (–10)	89^{ab} (–2)	85.50b (–6)	3.87^{de} (+24)	3.48^{f} (+12)	3.67^{d} (+18)	5.89^{e} (–28)	7.45^{b} (–9)	6.67^{b} (–18)
Mean	84.67^{NS}	86.67		4.08^{a}	3.66^{b}		5.95^{b}	6.82^{a}	
LSD 5%	Extract = 3.55 Interaction = 5.01			Conc. = 0.07 Extract = 0.13 Interaction = 0.18			Conc. = 0.10 Extract = 0.17 Interaction = 0.25		

Conc.: concentration.

index with whole plant extract was statistically at par with stem and fruit extract. The highest GI was recorded in control followed by root extract. There was significant reduction in GI of chickpea seeds when they were treated with different *E. dracunculoides* plant extracts. The highest (39%) reduction in GI was observed with leaf extracts and was followed by whole plant (25%) and stem extracts (25%) when compared with control. Lowest reduction (18%) was noted in root extract in comparison with control. Chickpea seed GI and MGT were significantly affected by extract contrations indicating delayed germination and poor GI with 1:10 concentration while the germination percentage remained unaffected.

Experiment II

Extract of different parts of *Euphorbia dracunculoides* and their concentrations produced a significant effect on emergence percentage of chickpea seeds (Fig. 1a). The lowest emergence was recorded in seeds treated with leaf extract at 1:10 (w/v) concentration followed by whole plant extract at the same concentration. The highest emergence was in stem extract at 1:20 (w/v) concentration which was statistically at par with fruit and whole plant extract at the same concentration and stem extract at 1:10 (w/v) concentration. Chickpea seed emergence was reduced by nearly 85, 44 and 19% when they were subjected to leaf, whole plant and root extract, respectively. In contrast, approximately 11% increase was observed with stem extract over distilled water.

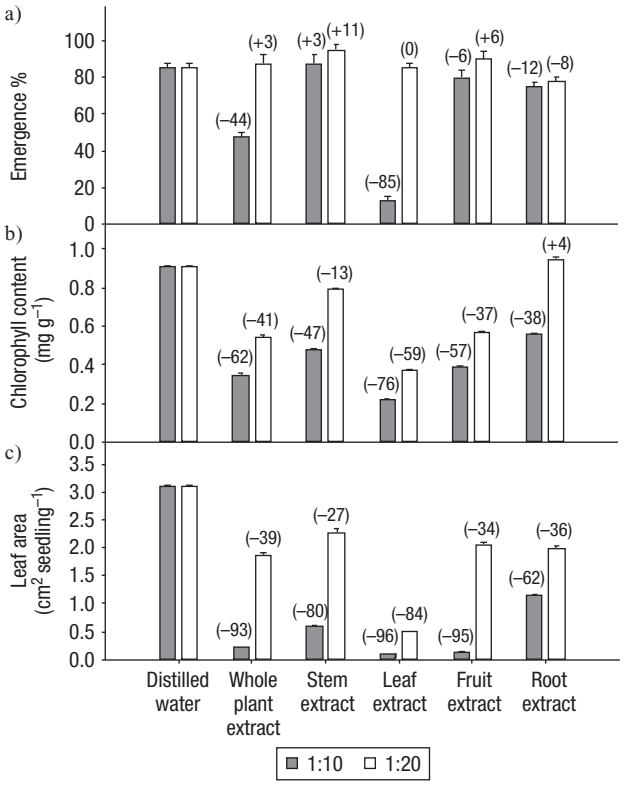

Figure 1. Phytotoxic effects of aqueous extracts of *E. dracunculoides* on emergence % (a), chlorophyll content (mg g^{-1}) (b) and leaf area per seedling (c) of chickpea. Figures in parenthesis show % increase (+) or decrease (–) over distilled water.

All the traits of chickpea seedling growth were adversely affected by the application of *E. dracunculoides* extracts (Table 2). Both root and shoot length, their individual and collective dry weight were significantly ($p \leq 0.05$) affected and the effects were more pronounced on root development than shoot growth. Chickpea seedlings grown in leaf extract produced minimum root and shoot length while it was maximum with distilled water. The application of leaf and whole plant extract depicted about 81 and 60% reduction in root length, respectively, whereas reduction in shoot length was 69 and 46%, respectively. Likewise the root and shoot dry weights individually and collectively were also severely affected by leaf and whole plant extract depicting 83 and 52% reduction in root dry weight, 68 and 40% reduction in shoot dry weight and 75 and 45% reduction in total dry weight over control, respectivly.

Euphorbia dracunculoides extracts produced a significant effect on SVI (Table 2). The statistically lowest SVI was recorded in seedlings subjected to leaf extract which was statistically at par with whole plant extract The statistically maximum SVI was recorded with control followed by leaf extract. Decrease in SVI was maximum (82%) with leaf extract followed by whole plant extract (63%) whereas reduction was minimum (24%) with stem extract.

The results indicated that extract prepared from *E. dracunculoides* leaves caused maximum suppression in chlorophyll contents of chickpea seedling followed by whole plant extract at both concentrations. The inhibitory effects increased with increasing concentration of extracts. Root extract at lower concentration (1:20) exhibited a 4% increase in chlorophyll contents over control while all other treatements showed reduction in chlorophyll (Fig. 1b). Chickpea seedlings treated with all extract of *E. dracunculoides* showed significant reduction ($p \leq 0.05$) in leaf area (Fig. 1c). Higher reductions were observed with 1:10 compared to 1:20 concentrations. A maximum reduction (96%) in leaf

Table 2. Phytotoxic effects of aqueous extracts of *E. dracunculoides* on seedling growth of chickpea. Means sharing the same letter in a column did not differ significantly at 5% probability level. Figures in parenthesis show % increase (+) or decrease (–) over control

Extract	Root length (cm)			Shoot length (cm)			Root dry weight (mg)			Shot dry weight (mg)			Total dry weight (mg)			Seedling vigor index		
	1:10	1:20	Mean	1:10	1:20	Mean	1:10	1:20	Mean	1:10	1:20	Mean	1:10	1:20	Mean	1:10	1:20	Mean
Distilled water	14.7^{a}	14.7^{a}	14.8^{a}	16.2^{a}	16.16^{a}	16.16^{a}	38.6^{a}	38.6^{a}	38.6^{a}	40.7^{a}	40.7^{a}	40.7^{a}	79.45^{a}	79.4^{a}	79.4^{a}	1,256.1^{b}	1,256.1^{b}	1,256.1^{a}
Whole plant extract	2.3^{h} (–84)	9.4^{d} (–37)	5.8^{e} (–60)	4.5^{h} (–72)	12.82^{c} (–21)	8.66^{c} (–46)	13.6^{g} (–67)	23.8^{d} (–38)	18.7^{e} (–52)	21.8^{ef} (–46)	27.4^{c} (–33)	24.6^{c} (–40)	35.5^{g} (–55)	51.3^{e} (–35)	43.4^{d} (–45)	108.7^{hi} (–19)	815.1^{e} (–35)	461.9^{e} (–63)
Stem extract	6.3^{f} (–58)	14.4^{a} (–3)	10.3^{b} (–30)	8.8^{f} (–45)	14.28^{b} (–12)	11.58^{b} (–28)	18.0^{e} (–53)	25.4^{c} (–34)	21.7^{b} (–44)	20.6^{g} (–49)	34.4^{b} (–15)	27.5^{b} (–32)	38.6^{f} (–51)	59.9^{c} (–25)	49.3^{b} (–38)	547.8^{f} (–56)	1367^{a} (+8)	957.4^{b} (–24)
Leaf extract	0.36^{i} (–98)	5.1^{g} (–65)	2.8^{f} (–81)	0.58^{i} (–96)	9.57^{e} (–41)	5.04^{d} (–69)	2.1^{i} (–95)	11.0^{h} (–72)	6.5^{f} (–83)	2.4^{h} (–94)	23.6^{d} (–43)	13.0^{d} (–68)	4.5^{i} (–94)	34.7^{g} (–56)	19.6^{e} (–75)	4.3^{i} (–99)	436.9^{g} (–65)	220.6^{f} (–82)
Fruit extract	2.6^{h} (–82)	11.9^{c} (–19)	7.3d (–51)	7.1^{g} (–56)	16.39^{a} (+1)	11.75^{b} (–27)	11.2^{h} (–71)	28.7^{b} (–26)	19.9^{d} (–48)	21.2^{fg} (–46)	35.3^{b} (–42)	28.2^{b} (–31)	32.4^{h} (–59)	64.1^{b} (–19)	48.3^{b} (–39)	209.9^{h} (–83)	1076.3^{c} (–14)	643.1^{d} (–48)
Root extract	7.0^{e} (–52)	12.5^{b} (–16)	9.8^{c} (–34)	10.9^{d} (–32)	12.50^{c} (–23)	11.72^{b} (–27)	15.3^{f} (–60)	25.8^{c} (–33)	20.5^{c} (–47)	22.6^{de} (–44)	27.9^{c} (–13)	25.2^{c} (–38)	38.0^{f} (–52)	53.8^{d} (–32)	45.9^{c} (–42)	529.5^{fg} (–57)	965.4^{d} (–21)	747.4c (–40)
Mean	5.6^{b}	11.3^{a}		8.02^{b}	13.62^{a}		16.4^{b}	25.6^{a}		21.5^{b}	31.5^{a}		38.0^{b}	57.19^{a}		442.7^{b}	986.1^{a}	
LSD 5%	Conc. = 0.19 Extract = 0.33 Interaction = 0.47			Conc. = 0.23 Extract = 0.41 Interaction = 0.58			Conc. = 0.32 Extract = 0.57 Interaction = 0.80			Conc. = 0.49 Extract = 0.85 Interaction = 1.20			Conc. = 0.72 Extract = 1.25 Interaction = 1.76			Conc. = 45.16 Extract = 78.23 Interaction = 110.63		

Conc.: concentration.

area was observed in seedling with leaf extract which was not statistically different from fruit extract and whole plant extract. Results also revealed that the interaction between concentration and types of extracts was significant at $p \leq 0.05$.

Experiment III

The soil collected from *E. dracunculoides* infested field significantly and negatively affected the emergence percentage, SVI and chlorophyll contents of chickpea seedlings, whereas NPK contents were positively influenced compared with the control soil (Table 3). Soil from *E. dracunculoides* grown field caused 55, 23 and 19% reduction in SVI, emergence percentage and chlorophyll contents, respectively. Contrarily an increase of 16, 6 and 4% was recorded in P, N and K contents of chickpea seedlings, respectively over seedling raised in control soil (Table 3).

Discussion

Inhibition of chickpea germination increased with increasing concentration of extracts of different parts of *E. dracunculoides*. Mishra *et al*. (2001) and Xiangxiang *et al*. (2009) reported that increasing concentration of *Asphodelus tenuifolius* and *Hemistepta lyrata* extract adversely affected the germination of wheat, mustard, lentil and chickpea; wheat, sorghum, cucumber, rape and radish seeds, respectively. Maximum reduction in germination percentage of chickpea seeds with aqueous extract of fruit at 1:20 concentration could be due to more inhibitory effect of allelochemicals present in fruit. Delayed germination and less GI with leaf extract of *E. dracunculoides* at 1:10 (w/v) concentration may reflect the presence of allelochemicals in maximum concentration. Tanveer *et al*. (2008) reported similar results by using leaf leachates of *Xanthium strumarium*, which caused maximum reduction in germination, MGT and GI of wheat, barley, maize, rice, cotton and sunflower.

Reduction in emergence percentage of chickpea seeds with leaf extracts could be due to the availability of inhibitory chemicals in higher concentration in leaf parts than others. Further, stimulatory effect observed with stem extract might be due to the lower concentration of allelochemicals in this extract because slight change in concentration may modify the functions of allelochemicals. Xingxiang *et al.* (2009) observed that

Table 3. Phytotoxic effects of *E. dracunculoides* infested soil on seedling growth, chlorophyll, N, P, and K content of chickpea. Means sharing the same letter in a column did not differ significantly at 5% probability level. Figures in parenthesis show % increase (+) or decrease (–) over control soil

Treatment	Emergence (%)	Seedling vigor index	Chlorophyll content (mg g^{-1})	N content (%)	P content (%)	K content (%)
Control soil	97.50[a]	603.00[a]	0.73[a]	2.23[b]	0.38[b]	1.13b
Test soil	75.20[b] (–23)	270.55[b] (–55)	0.59[b] (–19)	2.37[a] (+6)	0.44[a] (+16)	1.18[a] (+4)
LSD 5%	8.65	66.10	0.026	0.042	0.034	0.033

H. lyrata extracts stimulated the growth of roots and hypocotyls of *Sorghum vulgare* and *Cucumis sativus* at lower concentrations, while it inhibited their growth at higher concentrations. These results are also in accordance with the findings of Ahmad *et al*. (2007) who reported that aqueous leaf extracts of *Lantana camara* caused strong inhibitory effect on germination of test crops, whereas the lower concentration showed stimulatory effect in some cases.

The significant reduction in shoot and root length and dry weight of chickpea seedlings by different plant part extracts of *E. dracunculoides* at two concentrations could be due to the presence of water soluble inhibitors (Kil and Yun, 1992). All the traits of chickpea seedling growth were more adversely affected by the application of *E. dracunculoides* leaf extract at 1:10 concentration. This indicated the availability of inhibitory chemicals in higher concentration in leaf parts than others (Shukla *et al*., 2003). Dongre *et al*. (2004) reported that greatest inhibition of seedling growth in black gram (*Phaseolus mungo*) cultivars (P-19 and PU-35) was caused by leaf extracts of *Parthenium hysterophorus* at different concentrations. Varying rate of inhibition of chickpea seedling growth with aqueous extracts of *E. dracunculoides* parts at both concentrations (1:10 and 1:20) indicate that inhibitory effects of *E. dracunculoides* differed with plant parts and extract concentration. These results are in line with those of Aziz *et al*. (2008) who observed that fruit extract of *Gallium aparine* was more inhibitory than root, stem and leaf extract on germination and seedling growth of wheat.

The highest reduction in SVI with leaf extracts at both concentrations is supported by Channappagoudar *et al.* (2005) who reported that leaf extracts of *Commelina benghalensis* and *Cyperus rotundus* had greater inhibitory effect on SVI of sorghum, wheat, green gram, soyabean, sunflower and groundnut. The chlorophyll contents of chickpea seedlings were significantly reduced with different extracts. However, the detrimental effects were more conspicuous at 1:10 compared to 1:20 concentration showing that the responses were concentration dependent. It could be due to the presence of inhibitory chemicals in leaf parts of *E. dracunculoides*. These results are in line with the findings of Boby *et al*. (2002) who reported that aqueous extracts of *Ageratum conyzoides, Benincasa hispida* and *Eleusine indica* altered the chlorophyll contents of two upland rice cultivars, Lachit and Fapori ahu. Likewise, Batish *et al*. (2007a) observed a marked reduction in total chlorophyll contents of chickpea and pea plants with *Chenopodium murale* residues. The maximum reduction in leaf area of chickpea seedlings with leaf extracts could be due to the presence of water soluble inhibitors. Boby *et al*. (2002) reported that aqueous extracts of *A. conyzoides, B. hispida* and *E. indica* significantly reduced the leaf area of two upland rice cultivars, Lachit and Fapori ahu.

Decline in emergence percentage, chlorophyll contents and SVI of chickpea in *E. dracunculoides* infested soil could be due to bioactive molecules released from plant materials which may interact with the soil then taken up by chickpea plants. Similar results were observed by Batish *et al*. (2007a) on growth of chickpea seeds in soil infested with *Chenopodium murale*. Increase in NPK percentage could be due to the enrichment of soil infested with weed residues (Batish *et al*., 2007b). The higher concentration of NPK in chickpea seedlings could also be attributed to increased uptake of nutrients from the infested soil (Michelsen *et al*., 1995). Boby *et al*. (2002) reported that P content in Lachit and K content in Fapori ahu were increased by soil amendment with *B. hispida*.

Based on the present investigations, it could be concluded that aqueous extract of *E. dracunculoides* had

detrimental effect on seed germination and seedling growth of chickpea that increased with increasing concentration. *Euphorbia dracunculoides* contains compounds in its tissues which may cause phytotoxic effects under field conditions without depletion of available soil nutreints. Therefore, *E. dracunculoides* should be removed from fields at early stages to save chickpea from harmful effects of this weed.

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