

Allelopathic effects of *Parthenium hysterophorus* L. on germination and growth of onion

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ABSTRACT

In laboratory and greenhouse studies the aqueous extracts of leaf and flower of *Parthenium hysterophorus* drastically inhibited the germination and seedling growth of onion than stem and root extracts. Onion plumules were less sensitive to allelopathic effects than radicles. Increasing concentrations of extract severely inhibited the shoot growth. Root residues from growing parthenium reduced germination percentage (by 37%) followed by uprooted but not mixed (by 27%). Root residues however did not affect onion root and shoot lengths. Emergence percentage and rate were greatly reduced by rhizosphere soil collected from 0 to 15 cm radial distance from parthenium (13 and 17%, respectively). Root length greatly stimulated by rhizosphere soil whereas shoot length was not affected. This study indicated that parthenium has a clear allelopathic effect on onion germination and seedling growth even though the extent of inhibition was severe under laboratory than greenhouse conditions. Therefore, early removal of parthenium from onion fields is essential in order to minimize influences in terms of poor germination and retarded growth and the subsequent reduction in onion yield.

Key words: Allelopathy, aqueous extracts, bioassay, dry shoot residues, germination, onion, *Parthenium hysterophorus*, rhizosphere soil, root residues, seedling growth

INTRODUCION

Parthenium (*Parthenium hysterophorus* L., Asteraceae), a native of Americas, is now a major weed in Asia, Africa and Australia (15). It was introduced with food grains imported from subtropical North America into Ethiopia in 1970s and was first reported in 1988 (29,34). Subsequently it spread rapidly throughout the country, adversely affecting the crop production, biodiversity and animal husbandry (37). It is one of the invasive alien species registered in Ethiopia. Its successful spread in so many parts of world has mainly been attributed to its allelopathic properties, which enables it to compete effectively with native crops and/or pasture species (32,33). Furthermore, its allergic effects on human body makes hand-weeding more difficult.

Onion is most important vegetable crop in Ethiopia (2,16). One of the main reasons of its lower yields is competition from weeds, because it does not compete well with weeds. Thus, weeds reduce yield and quality of onion through competition for light,

moisture and nutrients (12). Currently, parthenium is threatening the onion production in Ethiopia.

The allelopathic effects of parthenium had been studied in Ethiopia on tef (37) and lettuce (39). However, little is known about the allelopathic potential of parthenium weed on onion seed germination and seedling growth. This study aimed to determine the allelopathic effects of parthenium on germination and seedling growth of onion under laboratory and greenhouse conditions.

MATERIALS AND METHODS

Naturally growing parthenium plants around our University campus were randomly uprooted and collected during flowering stage in August 2008. The plants were immediately brought to laboratory and separated into root, stem, leaf and flowers and cut into 2 to 3 cm pieces, air-dried in greenhouse and ground separately in a mill of 2 mm sieve size. Then 3, 6, 9 g of each ground materials were mixed in 100 ml distilled water and soaked for 24 h at room temperature (21 to 22°C) and filtered through two layers of cheesecloth. The aqueous extracts were stored in conical flasks in dark until use. Both in Laboratory bioassays or Greenhouse studies were done from August to December, 2008 and the rates of 3, 6, 9 g powdered material or 3, 6, 9 % extracts were based on the previous studies.

I. Laboratory bioassay

Onion seeds were surface-sterilized for 5 min in 1% sodium hypochlorite (NaOCl) solution and washed with de-ionized water for 3 min to remove all chemical residues. One hundred onion seeds were placed on double layers of Whatman No. 41 filter paper in 9 cm diameter Petri dishes and moistened with 10 ml of 3, 6 or 9 % aqueous extracts and distilled water (control). The treatments were replicated 4 times in a completely randomized design. The study was done in laboratory at room temperature (21 to 22°C). The experiment was conducted twice and the average data were used for analysis.

II. Greenhouse experiments

During the experimental period, the mean minimum and maximum temperatures were 12°C and 25°C and the relative humidity was 31 to 91%. The soil used for the experiment was clay-loam (organic matter 3 to 5%, pH 5.6 to 6.5). In all greenhouse experiments, 25 onion seeds were surface-sterilized for 5 min in 1% sodium hypochlorite (NaOCl) solution and washed with de-ionized water for 3 min to remove all chemical residues.

Soil incorporated dry shoot residues: Mature shoots were collected from naturally growing parthenium plants near our campus. The shoots were brought to laboratory and immediately cut into 2 to 3 cm pieces, air-dried in greenhouse and ground separately in a mill. Then 3, 6, 9 g ground materials were thoroughly mixed in 3.0 l pots filled with 3 kg sieved field soil. A pot filled with same soil without dry shoot residues was used as control.

Soil surface applied dry shoot residues: Dry shoot residues were prepared as per above experiment. The pots were filled with sieved agricultural soil. Then 3, 6, 9 g of ground materials were applied on the soil surface. A pot filled with the same volume of sieved agricultural soil without dry shoot residues was used as control.

Root residues: The pots were filled with sieved agricultural soil and 15 parthenium seeds were sown per pot. Pots without parthenium were used as control. A week after germination, the seedlings were thinned to 10 per pot and allowed to grow. Forty days after sowing, 4-treatments [(i). parthenium uprooted, (ii). parthenium uprooted and the soil thoroughly mixed, (iii). parthenium not uprooted] and (iv). control (no parthenium) were applied.

Rhizosphere soil: Soil samples were collected from the root zone of naturally growing parthenium at radial distances of 0-15 cm, 15-30 cm and 30-45 cm from the collar of the parthenium plant to 15 cm depth. Sieved soils were filled into 2.0 l pots. Control treatments were filled with sieved agricultural soil obtained from places free from parthenium and other weeds.

Data collection and analysis: Seeds germination data were collected daily from 4 to 9 days after sowing. Radicle and plumule lengths (laboratory bioassay) and root and shoot lengths (greenhouse experiments) were recorded on 9th day, by taking 10 seedlings at random. The rate of germination/emergence (G/ER) was calculated by the modified formula (24) as:

G/ER (seeds per day) =

$$\frac{\text{Number of normal seedlings}}{\text{Days of first count}} + K + \frac{\text{Number of normal seedlings}}{\text{Days of final count}}$$

Data were subjected to analysis of variance (ANOVA). Means were compared for all significant parameters using Least Significant Difference (LSD) test. Data analysis was performed using GenStat statistical package, GenStat for Windows 11th Edition (38). The inhibition percentage was calculated using the following equation modified from (11):

$$\text{Inhibition percentage (\%)} = \left(\frac{\text{Treatment} - \text{Control}}{\text{Control}} \right) * 100$$

RESULTS AND DISCUSSION

I. Laboratory bioassay

The aqueous extracts of parthenium leaves and flowers, inhibited the onion germination and seedling growth (Fig. 2). The parthenium aqueous extracts from flower and leaves are more inhibitory to different crops than stem and roots (22,37,39). In this study, similar results were obtained. Parthenium flower was more inhibitory to onion

germination (%) and rate (Fig. 1), and radicle and plumule lengths (Fig. 2) than leaf, stem and roots. The allelopathic effects of extracts from various plant parts are different owing to their variable concentrations of allelochemicals (4,13).

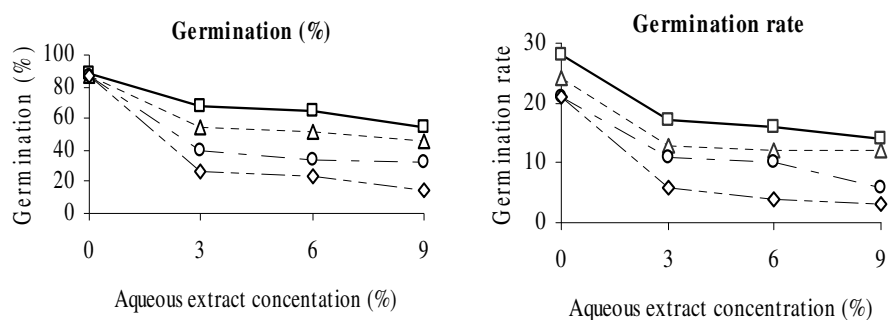


Figure 1. Effects of parthenium root, stem, leaf and flower aqueous extracts on onion seeds germination (%) and germination rate (seeds/day) in lab bioassay. Root aqueous extract: □—□, Stem aqueous extract: Δ—Δ, Leaf aqueous extract: ○—○, Flower aqueous extract: ◇—◇.

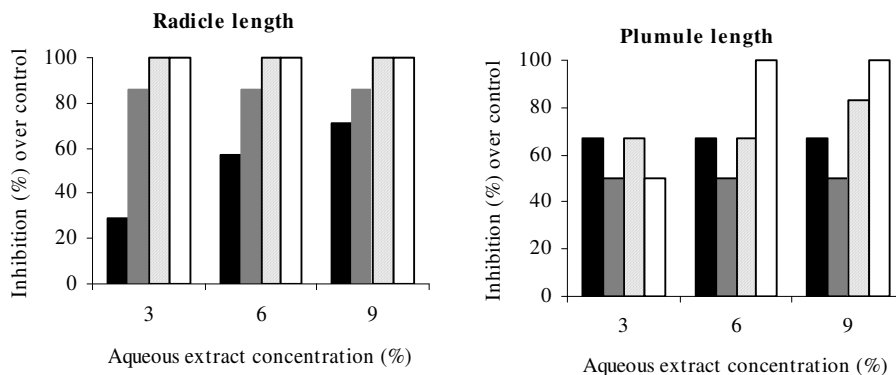


Figure 2. Influence of aqueous extracts of parthenium root (black), stem (grey), leaf (stripes) and flower (white) on radicle and plumule length of onion.

The increasing concentrations of aqueous extracts of root, stem, leaf and flower parts of parthenium decreased the germination (%) and rate (Fig.1). Similarly, inhibition of radicle and plumule lengths increased with increasing aqueous extract concentrations (Fig. 2). Thus inhibitory effects of aqueous extracts on germination and seedling growth were concentration dependent. The present results agree with reports on tef (37) and lettuce (39). Concentration dependence of allelopathic effects also has been reported for other plant species (1).

Onion radicles proved more sensitive to parthenium extracts than plumules. Because the complete failure of radicle growth occurred in parthenium flower and leaf aqueous extracts at all concentrations. However, complete failure of plumule growth was observed only in parthenium flower extract at 6 and 9% extract concentrations (Fig. 2). Perhaps because the radicles remain in direct contact with aqueous extracts i.e. allelochemicals. This finding agrees with several other reports (37,39).

II. Greenhouse experiments

Effects of soil incorporated dry shoot residues

The soil incorporation of shoot residues decreased both germination and seedling growth of onion. There was an increase in inhibitory effect with increase in amount of dry shoot residues incorporated. However, no significant difference was observed between control and 3 g for both germination (%) and rate, and root and shoot lengths (Table 1 and Fig. 3). The reduction in growth of *Brassica* species increased with the increasing amount of parthenium residues added to the soil (28). Other reports also indicated similar results for different plants (3,5,6,9,10,17,26, 35,41).

Table 1. Effects of parthenium soil incorporated and soil surface placed dry shoot residues on seedling emergence and growth of onion in greenhouse

Shoot residue (g/pot)	Emergence (%)		Emergence rate (seeds/day)		Root length (mm)		Shoot length (mm)	
	SI ¹	SS	SI	SS	SI	SS	SI	SS
0	78 a ²	74 a	10 a	7 a	67 a	38 a	63 a	54 a
3	66 a	18 b	10 a	3 b	61 ab	7 b	58 ab	16 b
6	41 b	2 c	7 b	1 c	46 b	0 b	50 b	1 c
9	34 b	1 c	4 c	0.4 c	30 c	0 b	33 c	0 c
LSD	17.21	4.12	2.26	0.90	15.90	9.87	13.21	12.10

¹SI: Soil incorporated, SS: Soil surface ; ²Means followed by different alphabets in the same column differ significantly ($P < 5\%$) as established by Fisher's protected LSD-test

Effects of soil surface applied dry shoot residues

Compared to soil incorporated dry shoot residues, the soil surface applied dry shoot residues drastically inhibited the onion germination and seedling growth (Fig. 3). This is congruent with previous report (20). All rates of soil surface placed parthenium dry shoot residues significantly inhibited the onion seedling emergence (%) and rate and root and shoot lengths over the control (Table 1 and Fig. 3). The possible explanation could be physical interference with upward movement of emerging seedlings (36) or due to the release of inhibitory allelochemicals from plant residues (7).

In both emergence (%) and rate, and root and shoot lengths, the inhibitory effects increased with an increase in amount of surface placed dry shoot residue. However, there was no significant difference between 6 and 9 g for emergence (%) and rate and shoot length and root length. Complete failure of root growth was observed at 6 and 9 g,

whereas, complete failure of shoot growth was observed at 9 g only (Table 1 and Fig. 3). This is in agreement with previous reports that found an increase in inhibitory effects with increasing amount of residue incorporated (3,6,10,30,41).

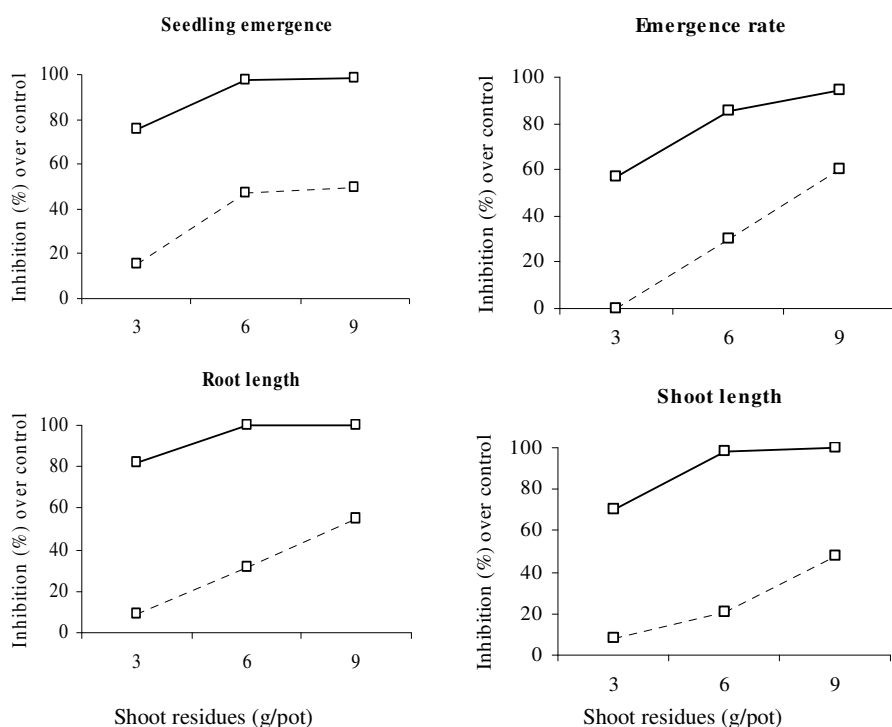


Figure 3. Inhibitory effects of method of application of parthenium dry shoot residues on the seedling emergence and growth of onion in pot culture. Soil incorporated: ----, Soil surface applied: —.

Effects of root residues

Parthenium root residues significantly inhibited the onion seedling emergence (Fig. 4). All treatments decreased the seedlings emergence (%) and rate than control. However, there was no significant difference between control and uprooted and mixed. Similarly, there was no significant difference between uprooted but not mixed and not uprooted. When parthenium was kept growing (not uprooted, NU), it greatly reduced the germination (37%) followed by uprooted but not mixed (UNM) (27%). However, there was a significant difference between uprooted and mixed (UM) and not uprooted (NU).

The root residues (exudates) of some plant species are toxic to roots of neighboring plants and also inhibit the germination of some other plant species (4,14,28). This study clearly showed the inhibitory effects of root residues on emergence (%) and rate. However, the root residues of parthenium did not influence the root and shoot lengths

(data not shown). This could be because the amounts of allelochemicals available in the root zone were not sufficient to cause inhibition. Several reports indicate that allelochemicals at lower concentrations are stimulatory rather than inhibitory (21).

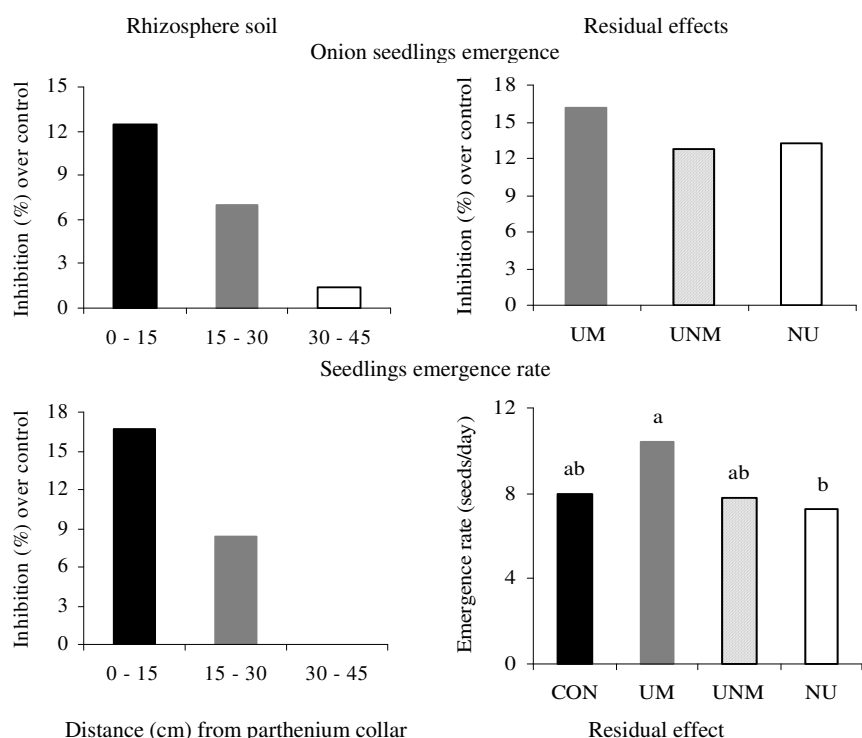


Figure 4. Effects of parthenium rhizosphere soil (0-15 cm: black, 15-30 cm: grey, 30-45 cm: white) and residual effects on seedlings emergence and emergence rate of onion. CON: Control (black), UM: Uprooted and mixed (grey), UNM: Uprooted not mixed (stripes), NU: Not uprooted (white).

Effects of rhizosphere soil

The parthenium rhizosphere soil significantly reduced the onion seedling emergence (Fig. 4 and Table 2). The rhizosphere soil collected from 0-15 cm distance was most inhibitory (13% reduction) followed by 15-30 cm distance (7% reduction). Compared to control, all soils collected from different radial distances from the collar decreased the emergence rate. The soil collected from 0-15 cm radial distance from the collar reduced the emergence rate by 17%. However, there was no significant difference between control and 15-30 cm and 30-45 cm.

Table 2. Effects of parthenium rhizosphere soil on seedlings emergence and growth of onion in greenhouse

Distance (cm) from the collar of parthenium	Emergence (%)	Emergence rate (seeds/day)	Root length (mm)
Control	72 a ¹	12 a	56 b
0 -15	63 b	10 b	70 a
15- 30	67 ab	11 ab	77 a
30- 45	71 a	12 a	76 a
LSD	6.08	1.272	10.07

¹Means followed by different alphabets in the same column differ significantly ($P < 5\%$) as established by Fisher's protected LSD-test.

Thus soil collected from closer to the root zone of parthenium resulted in greater inhibition. In soil from rhizosphere at 10, 20 and 30 cm radial distance from parthenium, the total phenolic acid content on dry weight basis was 0.025, 0.02, 0.015 and 0.011 (%) respectively (22). Phenolic acids plays key role in parthenium allelopathic potential.

On the contrary, the parthenium rhizosphere soil significantly stimulated the onion root length (Table 2 and Fig. 5). Root length was greatly stimulated by rhizosphere soil collected from all distance from the collar of parthenium plant than control. The stimulation at 0-15 cm, 15-30 cm and 30-45 cm distances was 25, 38 and 36%, respectively. However, there was no significant difference between the 15-30 and 30-45 distance rhizosphere soils. This is because allelochemicals stimulate germination and growth at lower concentrations (21). The greater stimulation could be due to lower concentration of allelochemicals available to onion roots.

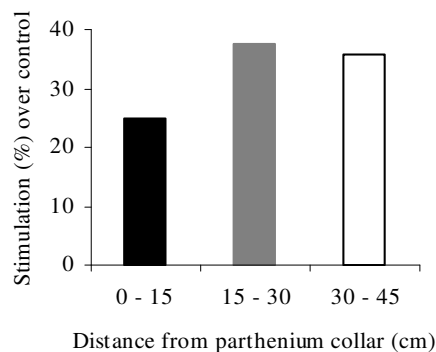


Figure 5. Stimulatory effects of parthenium rhizosphere soil (0-15: black, 15-30: grey, 30-45: white) on root growth of onion.

The *Parthenium hysterophorus* aqueous extracts, dry shoot residues, root residues and rhizosphere soil inhibited the germination and seedling growth of onion. The inhibitory effects were severe under the laboratory than in greenhouse conditions, because various biotic and abiotic processes reduce allelochemicals concentrations and availability

after they are released into the soil. Such processes includes use by soil microorganisms (8), chemical transformation into other compounds (27), sorption by soil organic matter and clay minerals (19), polymerization (40) and the extent of contact with roots (8).

The allelochemicals released from parthenium roots (18), stems (25), leaves (32) and flowers (31) affecting many plant species are sesquiterpene lactones and phenolics (33). Parthenin is the major sesquiterpene lactone whereas caffeic, vanillic, ferulic, chlorogenic, and anisic acids are the major phenolics (22). These two synergistically acting groups of allelochemicals significantly decrease the seed germination and subsequent growth of cabbage, when treated with extracts of parthenium leaf and inflorescence (23). This might be the possible reason for the current allelopathic inhibitory effect of parthenium on onion germination and seedling growth.

CONCLUSIONS

The higher amount of parthenium flower and leaf added to the soil caused drastic inhibitory effects on onion germination and seedling growth. The residues of parthenium plants growing in onion fields and added into soil reduced the germination, growth bulb yield of onion. Thus early removal of parthenium from onion fields is essential to avoid poor germination, retarded growth and lower bulb yield of onion crop.

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