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Full Length Research Paper

Phytotoxicity of *Parthenium hysterophorus* residues towards growth of three native plant species (*Acacia catechu* willd, *Achyranthes aspera* L. and *Cassia tora* L.) in Himachal Pradesh, India

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***Parthenium hysterophorus* is a strong allelopathic plant which belongs to the family Asteraceae of flowering plants. It is a rapidly spreading invasive plant species in the state of Himachal Pradesh up to 2000 m altitude. The allelochemicals produced by *P. hysterophorus* showed powerful toxic effects on the growth of other plant species. These allelochemicals are either phytotoxic phenolics or flavonoids. The study indicates that residues of *P. hysterophorus* species when mixed in soil adversely affect the germination and the subsequent seedling growth of native plants (*Acacia catechu, Achyranthes aspera* and *Cassia tora*). These allelochemicals in the soil are released by leaching or decomposition and they directly or indirectly affect plant growth by altering the physico-chemical properties of soil. A gradual decrease was observed in the germination, root and shoot length and in dry weight of seedlings of native plants with the increase in the concentration of amended soil residues (1, 2 and 4%). The maximum decrease in seedling dry weight was recorded in *A. aspera* (54.75%) followed by *A. catechu* (42.74%) and *C. tora* 40.25%) respectively at 4% concentration of plant residues.**

Key words: Allelochemicals, *Parthenium hyterophorus*, phenolics.

INTRODUCTION

The allelopathic effects of *Parthenium hyterophorus* are well known throughout the World. It is a invasive plant from subtropical America having strong allelopathic properties due to the presences of water soluble chemicals known as phenolics. In 1956 *P. hyterophorus* was introduced accidentally in India through the imported food grains and at present it has occupied almost all parts of India (Ramaswami, 1997). In Himachal Pradesh it was established during the last 15 to 20 years (Dogra et al., 2009a). The invasive plant predominantly invades disturbed habitats, urban ecosystem and unattended habitats due to its high adaptability, ecological amplitude and allelopathic properties (Batish et al., 2002b). Upon establishment, it forms its own monocultures which inhibit the growth of other plant species in its vicinity (Kohli and Batish, 1994). In Australia invasion of *P. hysterophorus* was found responsible for the change in native grasslands, open woodlands and river banks (McFayden, 1992; Chippendale and Panetta, 1994). Similarly, in India it invaded in the various habitats and as a result responsible for change in structure and composition of native plant species of these habitats (Evans, 1997; Dogra et al. 2009b).

Parthenium hyterophorus become a major invasive plant in Himachal Pradesh and as a result responsible for the decrease in diversity and richness of native plant species in the invaded habitats (Kohli et al., 2004, 2006). The native plant species *Achyranthes aspera*, *Cassia tora* and *Acacia catechu* are the dominant plant species

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of this region. But in the recent years due to the rapid spread of *Partehnium*, their abundance, density and growth effected drastically (Dogra et al., 2009). Due to the above reasons, a study was carried out to understand the effect of *P. hyterophorus* residues on these important native plants upon amended with soils at various concentrations.

METHODOLOGY

Soil amendment of *P. hysterophorus* residues

The plants of *P. hysterophorus* were uprooted, cut into small pieces, shade-dried and powdered. The soils used in the experiment were collected from the upper surface (2 to 6 cm depth) of the *P. hysterophorus* invaded sites. Soil collected from *Parthenium* free area served as a control. The soils from both the sites were air dried, sieved, labeled as invaded and control soils. In another set, the control soil was amended with dried plant residues of *Parthenium*. Soil amendment for each residue was prepared at a concentration of 1, 2 and 4%. Soil from all groups that is, control, *Parthenium* -invaded and amended soils were filled in plastic pots (12 cm diameter) for further studies.

Growth studies

For growth studies, seeds of native plants (*A. catechu*, *A. aspera* and *C. tora*) were procured from the Neri Herbal Garden Hamirpur, Himachal Pradesh. The seeds of *A. catechu*, *A. aspera* and *C. tora* were sown in each of the pots filled with control, invaded and amended soils. In each pot, 10 seeds of each test plant were sown. Five sets of each type were maintained under natural conditions (temperature 28 ± 3°C humidity). All the pots were watered daily for 20 days. The plantlets/ seedlings that emerged gradually were carefully uprooted. The length of the root and shoot was measured and biomass of oven dried (at 80°C for 24 h) seedlings was measured.

Soil analysis

Soils from all groups were subjected to the following analysis:

1. Electrical conductivity and pH: The aqueous extract of the soil was prepared by suspending 1 part of soil with 2 parts of water. Then the pH and electrical conductivity was measured by using EcoScan digital pH meter and EcoScan Con 5 digital conductivity meter respectively.
2. Phenol content: The phenolic content of the soils was estimated by the method of Swain and Hillis (1959) using Folin- ciocalteu reagent.
3. Organic carbon and organic matter were estimated by the rapid titration method of Walkey and Black (1934).
4 Available N was estimated using alkaline potassium permanganate as per the method of AOAC (1960).
5. Available P was determined by the method of Olsen et al. (1954).
6. Available Na^+ and K^+ were estimated using ammonium acetate as per Bower and Gschwend (1952).
7. The available Ca^{2+}, Mg and Cl^- were determined by the methods given by Black (1973).

Statistical analysis

The length of root shoot and dry weight of seedling of test plants were expressed as mean values and compared to control group. These were analyzed by one-way ANOVA followed by separation of means using Duncan's multiple range test (DMRT) as per Duncan (1955). Significance of difference between soil characteristics of control and *Parthenium* invaded sites was determined using 2 sample *t*- test at P< 0.05 or P< 0.01.

RESULTS

Effect of *Parthenium hysterophorus* residues on native plants

The germination and growth of the native plants decreased sharply in the *Parthenium* amended soils. The seeds germination of *A. catechu, A. aspera* and *C. tora* in *Parthenium* invaded soils was decreased by 21.54, 21.03 and 18.60%, respectively as compared to control ones (Table 1). The decrease in the germination at 4% concentration was nearly same in *A. catechu*, *A. aspera* and *C. tora* that is, 67.90, 65.67 and 67.01% respectively. Further, a gradual decrease in root, shoot length and seedling dry weight was observed in all the native plants with an increase in the concentration of plant residues incorporated in the soil (Figure 1a). In the control group, the maximum root length of *A. catechu*, *A. aspera* and *C. tora* was 23.00 ± 1.80, 3.70 ± 0.26 and 9.40 ± 0.43 cm, respectively. Although, the root length did not exhibit any significant changes in the invaded soils as compared to control (Table 1), however, there was a decreased significant decrease in root length in soils amended with increased concentrations of the plant residues (Figure 1b). The highest decrease was at highest concentration that is, 4% in *C. tora* (65.63%) followed by *A. aspera* (64.86%) and *A. catechu* (50.54%). The maximum growth of shoot was in *A. catechu* (9.90 ± 0.46 cm) followed by *A. aspera* (4.10 ± 0.26 cm) and *C. tora* (6.93 ± 0.15 cm) in the control soils. The shoot length was decreased by 13.44, 10.49 and 4.76%, respectively in *Parthenium*-invaded soils as compared to the control ones (Table 1). Further, in residue amended soils, at 1% concentration the reduction was maximum in *A. aspera* (21.22%) followed by *C. tora* and *A. catechu*. After this, a significant decrease was observed in shoot length with increased concentration of residues in the soil (Figure 1c). The maximum decrease in shoot length was in *A. aspera* (55.37%) followed by *A. catechu* (47.48%) and *C. tora* (46.61%) at 4% concentration. Likewise, the dry weight of the species followed the similar pattern of inhibition in all the three test plant species grown in *Parthenium* invaded soil as well as residue amended soil. The maximum decrease in dry weight was recorded in *A. aspera* (54.75%) followed by *A. catechu* (42.74%) and *C. tora* (40.25%) respectively at 4% concentration of plant residue (Figure 1d). The correlation coefficient values showed a positive relationship between decrease in dry weight and increase in concentrations of the residue amended soils.

Table 1. Germination, root and shoot length and seedling dry weight of native plants in control and *Parthenium* invaded soil.

Plant species	Parameter	Control soil	Weed invaded soil
A. catechu	Germination (%)	93.33 ± 5.77	73.33 ±5.77*
	Root length (cm)	23.00 ± 1.80	20.00 ± 0.92 ns
	Shoot length (cm)	100 (9.90 ± 0.46)	86.56 (13.44)*
	Seedling dry weight (mg)	337.30 ± 7.14	303.85 ± 7.78 *
C. tora	Germination (%)	90.00± 10.00	73.33 ± 5.77*
	Root length (cm)	9.40 ± 0.43	8.57 ± 0.86 ns
	Shoot length (cm)	6.93 ± 0.15	6.60 ± 0.30 ns
	Seedling dry weight (mg)	28.90 ± 1.91	25.64 ± 1.78 ns
A. aspera	Germination (%)	96.67 ± 5.77	76.67 ± 5.77 *
	Root length (cm)	3.70 ± 0.26	3.10 ±0.10*
	Shoot length (cm)	4.10±0.26	3.67±0.41 ns
	Seedling dry weight (mg)	7.56 ± 0.59	6.40 ± 0.75 ns

*Means values significant and ns means values insignificant at 5% level of significance after applying two population *t* test.

Effect of residues on soil properties

The amount of phenolics in the *P. hysterophorus* invaded soil was 29.40 ± 0.57 mg/100 g and in control soil was 14.82 ± 0.42 mg/100 g, respectively (Table 2). The percent increase in the amount of phenolic contents in the invaded soil was 49.59% as compared to the control. The pH of the control soil was 7.62 and of *Parthenium* amended soil 7.80, respectively. The electric conductivity of the ions was increased by 18.21% in the invaded soil as compared to control soil. The amount of percent organic carbon and organic matter was equally increased in the invaded soil as compared to control ones. The amount of available N, P and K in the invaded soil was increased by 47.70, 51.31 and 39.89%, respectively. The amount of available calcium in the control soil was 5.83 ± 0.58 and 17.57± 0.60 g/100 g in the invaded soil. It was increased by only 16.51% in the *Parthenium* invaded soil. Further, the available magnesium and chloride increased by 12.99 and 26.57% in the *Parthenium* invaded soil.

DISCUSSION

The soil amended with *P*. *hysterophorus* was adversely affecting the native plant species as evident during present study in Himachal Pradesh under natural conditions. The major cause for these retardatory effects was due to some water soluble chemicals (allelochemicals) produced by invasive plants besides other hidden phenomena (Callaway and Ridenour, 2004). These allelochemicals have a strong effect on the growth of other plants in the invaded areas and as a result are responsible for invasive plants' success. Such effects may have long-term implications for plant invasions and the organization of plant communities (Thompson, 1999). *Centaurea maculosa* and *Centaurea diffusa* are well known destructive invasive plants in North America. The allelochemicals produced by their roots had shown powerful toxic effects on the growth of other plants and soil microbes (Bais et al., 2003; Weir et al., 2003; Vivanco et al., 2004; Callaway et al., 2004).

The present study indicates that residues of *P*. *hysterophorus* when mixed in soil adversely affect the germination and the subsequent seedling growth of native plants. The decrease in seed germination was up-to 21.54, 21.03 and 18.60%, in *A*. *catechu, A*. *aspera* and *C*. *tora* respectively in the invaded soils and this signifies the allelopathic effect of *Parthenium* residues in the invaded habitats. The productivity of the native plants (*A*. *catechu, A*. *aspera and C*. *tora*) decreased as reflected from the reduction in dry weight with the increased concentrations of added residues in the soils. The decrease was highest at 4% concentration of plant residues as evident by 54.75% decrease in *A*. *aspera,* 42.74% in *A*. *catechu* and 40.25% in *C*. *tora* respectively. It has been well documented that *P*. *hysterophorus* contain phytotoxic phenolics and flavonoids respectively (Sharma and Sharma, 1995). The allelochemicals in the soil either released by leaching or decomposition may either directly or indirectly affect plant growth by altering the physico-chemical properties of soil (Prati and Bosdorf, 2004).

Studies on the allelopathic effect of the invasive plant *Tribulus terrestris* on surrounding vegetation in an abandoned field of Kuwait was studied by El-Ghareeb in

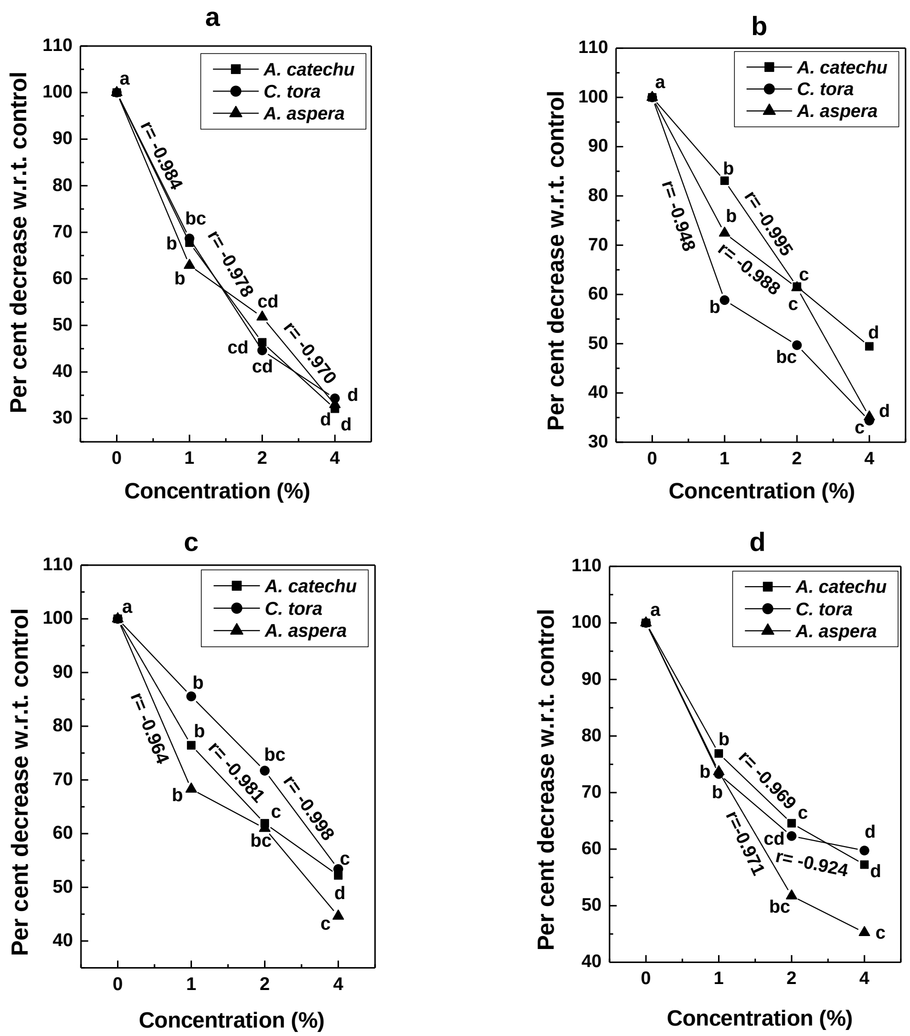

Figure 1. Effect of different concentrations of *Parthenium* residues amended in soil on (a) germination (b) root length (c) shoot length and (d) dry weight of native plants. Different alphabets around the curve represent significant difference at P<0.05.
'r' represents value of correlation coefficient.

Table 2. Comparison of selected physico-chemical properties of control soil and *Parthenium* invaded soil.

S/N	Parameter	Control	Invaded
1	Phenolics (µg/100 g soil)	14.82 ± 0.42	29.40 ± 0.57**
2	pH	7.62 ± 0.02	7.80 ± 0.02**
3	EC (µS)	328.10 ± 2.74	401.17 ± 8.01**
4	Organic carbon (%)	0.62 ± 0.07	1.02 ± 0.04**
5	Organic matter (%)	1.07 ± 0.12	1.75 ± 0.06 **
6	N (kg/ha)	88.62 ± 2.25	169.44 ± 2.09**
7	P (ppm)	62.22± 3.24	127.78 ± 5.17**
8	K (ppm)	70.32 ± 4.59	116.99 ± 3.26**
9	Na (ppm)	47.84 ± 2.46	68.46 ± 2.99**
10	Ca (g/100 g)	14.67 ± 0.29	17.57± 0.60**
11	Mg (g/100 g)	5.83± 0.58	6.70 ± 0.45**
12	Cl (g/100 g)	2.93 ± 0.21	3.99 ± 0.41**

** means significant from control at P< 0.01 after applying student *t*- test.

1991. His study demonstrated that besides the growth inhibitory effect of plant on other plants, the soil moisture and concentration of N, P and K were significantly higher in *T*. *terrestris* site. In the present study too the amount of available nutrients was significantly more in *Parthenium*-invaded soils as compared to the control ones. Abundant evidences support the idea that higher resource availability increases the susceptibility to invasion of plant communities (Maron and Connor, 1996). Further, the absorption of phenolics - the allelopathic compounds- by soil particles and their microbial breakdown and may account for the outcome of present observations (Dalton, 1999; Huang et al., 1999; Wardle et al., 1998) which are further affected by various soil factors such as soil texture, organic carbon and organic matter etc., (Kobayashi, 2004).

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