Assessment of allelopathic efficacy of *Parthenium hysterophorus* L. plant parts on seed germination and seedling growth of *Phaseolus vulgaris* L.

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Abstract. In the current study an endeavor was been made to appraise the allelopathic effects of *Parthenium hysterophorus* L. leaf, stem and flower extracts on growth and seedling related traits of *Phaseolus vulgaris* L. The *Parthenium hysterophorus* leaf, stem and flower extracts showed inhibitory activity on germination, shoot length, root length, seed vigour, tolerance index, root length, shoot length, fresh and dry weight of bean seedlings. All the parameters were found to be decreased with increase in the concentration of aqueous leaf, stem and flower extracts except phytotoxicity, when compared to control. The maximum and minimum value was observed for all these parameters in 2% and 10% concentration, except phytoxicity respectively, when compared to control. The result of the present study showed that inhibitory effects of *Parthenium hysterophorus* leaf, stem and flower extracts that may be due to the presence of some allelochemicals.

Keywords: Allelopathy, Bean, Parthenium.

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Introduction

Agriculture sector particularly crop production is under gigantic demands. Weeds, insect-pests, diseases, abiotic stresses and imbalanced crop nutrition are chief threats to crop production. Unfavorable climatic changes are another big threat to global food security. Due to rising temperature and uneven distribution of rainfall, crop growth is adversely affected, which causes substantial yield reduction (McDonald et al., 2009). Allelopathy is an interesting but complex mode of interaction between plants, accomplished through the release of chemical substances into the environment. The term “allelopathy” signifies the interactions between plants might lead to either encouragement or embarrassment of growth. Different groups of plants like algae, lichens, annual and perennial weeds have wide known allelopathic interactions (Kruse et al., 2000).

The term ‘allelopathy’ is today generally accepted to cover both inhibitory and stimulatory effects of one plant on another plant (Rice, 1984). Secondary metabolites in plants have been investigated by phytochemists, and many complex biological functions have been discovered. Various secondary metabolites produced by plants and microorganisms have been considered as prospective allelochemicals and to play an important role in shaping interactions and communities.

Compounds that have been identified thus far include a variety of chemical classes such as phenolic acids, coumarins, benzoquinones, terpenoids, glucosinolates, and tannins (Putnam and Duke, 1978). These and other allelochemicals are found in many plant species from woody to herbaceous plants, grasses and broadleaves, weeds and crops. Allelochemicals can act on plants in a variety of ways, such as inhibiting germination by disrupting cell division, interfering with mechanisms of energy transfer (respiration, and limiting water and nutrient uptake). The overall effect is to severely impede the growth of the plant. There are many details left to be determined such as regulation and production stimuli and mode of action for inhibition. It is also not readily understood to what extent allelopathic compounds interact with each other and other chemical compounds within the rhizosphere to inhibit surrounding plants (Weir et al., 2004).

During active plant growth, particularly in early growth stages or during periods of stress, root exudation, either through diffusion, ion channels or vesicle transport, is the primary method for release of many organic and inorganic compounds into the rhizosphere. Recently, several reports have suggested that allelopathy holds great prospects for finding alternative strategies for weed management. Thereby, the reliance on traditional herbicides in crop production can be reduced (An et al., 1998; Inderjit and Keating, 1999). The current worldwide demand for cheaper, more environmentally-friendly weed management technologies has motivated a number of studies on the allelopathic interaction between crops and weeds (Omet et al., 2002). Weeds are the most aggressive, troublesome and undesirable plant of the world's vegetation and they interfere with seed germination, growth, productivity and yield of the cultivated crops cause enormous reduction in crop yield, wastages of resources and human energy and also a health hazard to human being.

Parthenium is an aggressive ubiquitous invasive annual herbaceous weed with no economic importance unraveled till now and has made wide distribution globally affecting the growth of native plants species. Parthenium is one of the ten worst weeds in the world and has been listed in the global invasive species database. It is native to tropical and subtropical America considered as a noxious weed because of its prolific seed production and fast spreading ability, allelopathic effect on other plants, strong competitiveness with crops and health hazard to human as well as animals.

Phaseolus vulgaris is a herbaceous annual plant, grown worldwide for its edible beans, used both dry and green. It is a highly polymorphic warm-season, annual herbaceous. The pods may contain 4 to 12 seeds. The seeds are 0.5-2 cm long, kidney shaped and highly variable in colour depending on the variety: white, red, green, tan, purple, gray or black. The common bean is high in starch, protein, minerals (iron and zinc) and vitamins and dietary fibers an excellent source of iron, potassium, selenium, molybdenum, thiamine, and vitamin B6.

Materials and methods

Collection of plant material and seed sample

The plant *Parthenium hysterophorus* was collected from in and around of Mysore University Campus, Manasagangotri and different areas of Mysore city. The seed sample of French bean (*Phaseolus vulgaris* L.) (Variety selection-9) was procured from Arjun agro agencies, Mysore, The seed samples were tested for their sensitivity to weed *Parthenium hysterophorus* L. by conducting preliminary germination experiments.

Preparation of aqueous extract

Mature plants of *Parthenium hysterophorus* L. were collected and immediately partitioned into shoot (stem + branch), leaf and flower. Shoot and leaf part of the fresh plant was cut into 1-2 cm pieces, shade dried for a week. The dried shoot, leaf and flower were then grinded separately using a mixer grinder made in to a fine powder. 2, 4, 6, 8 and 10 g powder of each plant part was weighed using electronic balance separately and soaked in 100 mL of distilled water separately and mixed thoroughly by keeping in rotatory shaker and left over night at the room temperature (21 $\pm$ 22 °C) to release allelochemicals contents in the solution. After 24 hours of soaking at room temperature, extracts were collected by sieving through muslin cloth or sterilized cotton and designated as 2, 4, 6, 8 and 10%

of each shoot, leaf and flower aqueous extracts, respectively.

Preliminary germination studies

As per the ISTA standard, 400 appropriately sized, healthy bean seeds were surface sterilized using 2% sodium hypochlorite for 2 to 3 min then the seeds were washed thoroughly with sterile distilled water to remove excess of sterilent. Ten uniform sized seeds were placed per petriplate evenly. The petriplates were previously surface sterilized with 70% alcohol. After placing seeds 10 mL of 2, 4, 6, 8 and 10% different concentrations of each shoot, leaf and flower aqueous extract of parthenium were poured for each petriplates. The petriplates were incubated in dark for four days. From 5th day onwards, the germinated seedlings were exposed to 12 h light intensity and seedlings were further grown up to 9 days. Three replicates of 400 seeds were kept for each concentration. One treatment was run as control with Hoagland's nutrient solution. During the period of germination, the seeds were examined daily to determine the onset of germination. Emergence of radical from seeds was considered as criteria for germination. Germination was expressed as percentage germination.

Germination studies: Germination refers to initial appearance of the radicle by visual observation. It was calculated by using the formula prescribed by ISTA (1985).

$$\%\ \text{Germination} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds plated}} \times 100$$

Vigour index: Vigour index of the seedling was calculated by using the formula suggested by Abdul-Baki and Anderson (1973). Length of the embryonic axis of the seedling was measured for the calculation of Vigour Index (VI) as follows:

VI = (Mean root length + Mean shoot length) x germination percentage

Tolerance index: Tolerance index was calculated by using the formula suggested by Turner and Marshal (1972). Longest root in treatment of the seedling was measured for the calculation of Tolerance Index (TI) as follows:

$$\text{T I} = \frac{\text{Longest root in treatment}}{\text{Longest root in control}} \times 100$$

Percentage of toxicity: The percentage of toxicity of the seedling due to parthenium treatment was calculated by the formula suggested by Chiou and Muller (1972) as follows:

$$\text{Phytotoxicity (\%)} = \frac{\text{Radical length of control} - \text{Radicle length of treated sample}}{\text{Radicle length of control}} \times 100$$

Morphological studies

To know the biomass of the seedlings, the fresh seedlings were weighed using electrical balance to determine the fresh weight. The seedlings were then dried in a hot air oven at 80 °C for 48 h and then dry weight was estimated in an electrical balance. The procedure was repeated with three replicates with one hundred seeds plated per replication. After an appropriate period, the length of roots and shoots were measured with a ruler and expressed in cm (Agarwal, 1994).

Results

The present investigation was aimed at finding out the effect of parthenium aqueous extracts of leaf, stem, and flower on germination and growth parameters of French bean. (Table 1). Percent germination was found to be decreased with increased concentration of all the three aqueous extracts when compared to control. The maximum percentage of germination was recorded in control (95%) compared to other concentrations. The maximum and minimum percentage of germination in leaf, stem and flower extract were observed in 2% and 10% concentration 81.66%, 75%, 56.66% and 15%, 13.33% and 6.68%, respectively.

Effect of different concentration of leaf, stem and flower aqueous extracts on

Table 1. Effect of different concentrations of aqueous leaf, stem and flower extracts of *Parthenium* on germination and early seedling growth parameters.

Parameters	Different concentrations of parthenium leaf extract					
	Control	2%	4%	6%	8%	10%
Germination %	99±0.816^{a}	81.66±2.357^{b}	65±4.082^{c}	48.33±2.357^{d}	41.66± 2.357^{e}	15±4.082^{f}
Vigour index	5,189.22±39.96^{a}	3,814.65±110.7^{b}	2,870.3±182.1^{c}	1,683.3±82.31^{d}	1,015.41± 68.28^{e}	119.15±32.94^{f}
T. index	100.00±0.00^{a}	92.70±0.062^{b}	88.01±0.101^{c}	62.32±0.164^{d}	47.91±0.443^{e}	18.74±0.691^{f}
Phytotoxicity	0.00±0.00^{f}	12.12±0.310^{e}	27.76±0.195^{d}	52.65±0.129^{c}	80.88±0.004^{b}	91.25±1.106^{a}
Root length (cm)	18.72±0.01^{a}	17.1±0.08^{b}	16.11±0.01^{c}	11.50±0.00^{d}	8.87±0.01^{e}	3.42±0.01^{f}
Shoot length (cm)	33.69±0.01^{a}	29.61±0.01^{b}	28.04±0.01^{c}	23.32±0.01^{d}	15.48±0.32^{e}	4.51±0.02^{f}
Fresh weight (g/plant)	3.56±0.008^{a}	2.94±0.008^{b}	2.80±0.012^{c}	2.64±0.012^{c}	2.52±0.012^{c}	2.47±0.012^{d}
Dry weight (g/plant)	0.37±0.012^{a}	0.28±0.012^{b}	0.25±0.012^{c}	0.22±0.008^{c}	0.19±0.012^{d}	0.16±0.012^{d}
Parameters	**Different concentrations of parthenium stem extract**					
	Control	**2%**	**4%**	**6%**	**8%**	**10%**
Germination %	98.33±1.247^{a}	75±4.082^{b}	55±4.082^{c}	38.33±2.357^{d}	31.66±2.357^{e}	13.33±2.35^{f}
Vigour index	5,101.47±63.30^{a}	3,398.08±186.9^{b}	2,117.9±158^{c}	1,106.43±683^{d}	670.76±50.86^{e}	70.06±12.7^{f}
Tolerance index	100.00±0.00^{a}	91.21±0.293^{b}	78.02±0.369^{c}	56.23±0.288^{d}	42.70±0.163^{e}	14.40±0.56^{f}
Phytotoxicity %	0.00±0.00^{f}	9.60±0.927^{e}	22.41±0.757^{d}	44.74±0.536^{c}	60.42±0.377^{b}	87.81±0.02^{a}
Root length (cm)	18.36±0.20^{a}	16.6±0.01^{b}	14.24±0.02^{c}	10.14±0.01^{d}	7.26±0.01^{e}	2.23±0.02^{f}
Shoot length (cm)	33.51±0.01^{a}	28.70±0.03^{b}	24.26±0.00^{c}	18.71±0.02^{d}	13.91±0.02^{e}	3.01±0.01^{f}
Fresh weight (g/plant)	3.24±0.012^{a}	2.89±0.012^{b}	2.77±0.012^{c}	2.39±0.012^{d}	1.84±0.012^{e}	1.10±0.012^{f}
Dry weight (g/plant)	0.34±0.012^{a}	0.25±0.012^{b}	0.22±0.012^{c}	0.21±0.008^{c}	0.17±0.012^{d}	0.11±0.012^{e}
Parameters	**Different concentrations of parthenium flower extract**					
	Control	**2%**	**4%**	**6%**	**8%**	**10%**
Germination %	97.33± 1.247^{a}	56.66 ±4.714^{b}	41.66±2.357c	26.66± 4.71^{d}	15± 4.082^{e}	6.68± 4.690^{f}
Vigour index	5,020.89±25.2^{a}	2,468.16±206.^{b}	1,438.15±83.^{c}	637.66±113.^{d}	184.11±49.^{e}	37.76±2.29^{f}
T. index	100.00±0.00^{a}	71.81±0.062^{b}	67.88±25.713^{c}	47.57±0.240^{d}	19.56±0.49^{e}	11.66±1.009^{f}
Phytotoxicity %	0.00±0.00^{f}	8.68±0.375^{e}	13.93±0.008^{d}	38.55±0.052^{c}	52.59±0.033^{b}	81.73±0.073^{a}
Root length (cm)	17.9±0.081a	15.73±0.016b	12.93±0.024c	8.47±0.016d	3.42±0.016e	1.56±0.205f
Shoot length (cm)	33.16±0.021a	27.82±0.020b	21.58±0.020c	15.43±0.020d	8.86±0.024e	2.21±0.024f
Fresh weight (g/plant)	3.08±0.012^{a}	2.53±0.016^{b}	2.38±0.012^{c}	1.91±0.008^{d}	1.81±0.016^{e}	0.37±0.012^{f}
Dry weight (g/plant)	0.32±0.012^{a}	0.22±0.012^{b}	0.20±0.012^{c}	0.18±0.012^{d}	0.15±0.008^{e}	0.08±0.012^{f}

Mean ±SE followed by same superscript are not statistically significant between the concentrations when subjected to SPSS package ver. 14.0 according to Tukey's mean range test at 5% level.

Vigour Index significantly decreased when to compared with control (Table 1). Maximum and minimum value of vigour index was recorded in control sets (5,189.22) and 10% aqueous extract of flower (37.76), respectively. Leaf and stem aqueous extracts showed more or less similar effect on vigour of seedlings. In leaf, stem and flower extract, maximum and minimum value of vigour index was recorded in 2% (3,814.65, 3,398.08 and 2,468.16; and 119.15, 70.06 and 37.76, respectively). Different concentrations of leaf, stem and flower extracts effects on tolerance index is represented in Table 1. Maximum tolerance index were observed in control (100.00%). Among three aqueous extracts, flower aqueous extract showed high percentage of inhibition in 10% extract (11.66). In leaf, stem and flower extract the maximum and minimum value was recorded in 2% and 10% (92.70, 91.21 and 71.81; and 18.74, 14.40 and 11.66, respectively). Phytotoxicity in French bean seedlings at different concentration of aqueous extracts was found to be significantly different (Table 1). Phytotoxicity increased with increase in concentration of aqueous extracts. Flower aqueous extract showed more phytotoxic effect than leaf and stem extracts. Maximum and minimum value with respect to phytotoxicity was recorded in 10% and 2% concentration of stem and flower extract (91.25, 87.81 and 81.73; and 12.12, 9.60 and 8.68, respectively).

Effect of aqueous extracts of leaf, stem and flower on root and shoot length of French bean seedlings is presented in the table 1. The root and shoot length decreased significantly as concentration of extract increased from 2% to 10%. In leaf, stem and flower extract, the maximum and minimum root and root length was recorded in 2% and 10% concentration (17.1, 16.6, and 15.73 cm; and 3.42, 2.23 and 1.56 cm; and 29.61, 28.70 and 27.82 cm; and 4.51, 3.01 and 2.21 cm, respectively). Effect of aqueous extracts of leaf, stem and flower on fresh weight and dry weight of French bean seedlings is presented in the Table 1. In aqueous extracts, fresh weight was found to be decreased with increased in concentration. In leaf, stem and flower extracts, maximum and minimum fresh weight was recorded in 2% and 10% concentration (2.94, 2.89, 2.53 mg/g F.Wt. and 2.47, 1.10 and 0.37 mg/g F.Wt., respectively). The dry weight also decreased with increase in concentration of aqueous extracts. In leaf, stem and flower extract the maximum and minimum dry weight were observed in 2% and 10% concentration (0.28, 0.25, 0.22 mg/g F.Wt.; and 0.16, 0.11, 0.08 mg/g F.Wt., respectively).

Discussion

Increasing global population is a threat to food security and agricultural sustainability. Allelopathy has emerged as a pragmatic approach to solve multiple issues in modern agriculture. Seed germination is a process in which major physiological activities are involved at metabolic levels. Any loss in the vigour due to parthenium extracts application reduces the germination. Based on the data obtained parthenium was found to be toxic to French bean above 10% concentration, which was indicated by the complete inhibition of germination above 10% concentration.

The leaf, stem and flower aqueous of parthenium inhibit germination in bean but degree of inhibition varied with change in concentration. Flower extract showed significantly high inhibition of germination compared to leaf and stem extract. Sesquiterpene lactones and phenolics, particularly parthenin are found to be inhibitory to seed germination and growth in many plants (Swaminathan et al., 1990). Oudhia (2001) have reported a significant allelopathic effect of parthenium extracts upon the seed germination and growth of wheat. In our present investigation vigour index and tolerance index significantly reduced with increasing parthenium concentration when compared to control. Flower extract more effectively reduced the vigour index than leaf and stem extracts, on the other hand phytotoxicity increased as the concentration increased. Seed vigour is a multiple complex, which is defined as sum total of those properties of seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence (Gholami and Sharafi, 2010).

The root and shoot lengths are significantly decreased when treated with different concentration of parthenium leaf, stem and flower extracts. The root and shoot length decreased with increase in concentration of extracts, when compared with control. The results were corroborated with the findings of Tawaha and Turk (2003) who reported that leaf extract of black mustard exhibited the greatest inhibition on oat shoot and root growth. Our findings correspond with results by Mersie and Singh (1987) who found strong relation between increased aqueous extract concentrations of *Parthenium hysterophorus* and increased toxicity to some agronomic crops and weed plants. Similarly Shruthi et al. (2014) reported significant reduction in radical and plumule length in green gram due to allelopathic effects of neem. The higher concentration of parthenium leaf extracts have greatly reduced the seed germination, shoot length, shoot weight, root length and root weight of soybean, mungbean and maize (Khan et al., 2011).

Parthenium hysterophorus retarded the seedling growth and reduced the fresh and dry matter production. The fresh weight and dry weight was highly affected as the concentration of extracts increased. It decreased with increase in concentration and dry weight was decrease slightly with increase in concentration of aqueous extracts of parthenium. Our results are similar with Swaminathan et al. (1990), who observed similar effect on maize and sorghum, pumpkin, and tomato. From the present study concludes that *Phaseolus vulgaris* was more sensitive to leaf, stem and flower extracts of *Parthenium hysterophorus*.

Conflict of interest statement

Authors declare that they have no conflict of interests.

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