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Phytotoxic effect of the extracts of *Parthenium hysterophorus* L. on the germination, seedling growth and biomass of some agricultural crops

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ABSTRACT

This study was conducted to assess the phytotoxic effect of invasive species: *Parthenium hysterophorus* L. on the germination, seedling length and biomass of *Zea mays*, *Macrotyloma uniflorum* and *Triticum aestivum*, in order to explore its potential as noxious species. In this study, the allelopathic substances were extracted with distilled water and methanol from the aerial and underground part of *P. hysterophorus* L. in different concentration (1, 100, 150, 400 mg mL^{-1}). The results of the study revealed that the methanol fraction of roots at 400 mg mL^{-1} concentration had the highest phytotoxic activity as compared to the double distilled water extract. Germination (%) was observed to be maximum (90%) for *Z. mays* with double distilled water above ground part extract at 1 mg mL^{-1} and lowest (10%) for *M. uniflorum* L. in 400 mg mL^{-1} both aerial and underground plant extracts at the last day of measurement. Mean shoot and root length were observed highest (17.6cm and 6.1cm respectively) in *Z. mays* with aerial double distilled water extract at 1 mg mL^{-1} concentration and it was found lowest (3.2cm and 2.8cm) in *M. uniflorum* with underground part double distilled water extract at 400 mg mL^{-1}. Biomass was recorded highest (1.97 g/100cm^2) in *Z. mays* in aerial part extract and lowest (0.83 g/100 cm^2) in horse gram in underground part extract at concentration of 400mg mL^{-1} with double distilled water extract. In methanol, both aerial and underground part extracts, the germination observed only at 1mg mL^{-1} concentration.

1) INTRODUCTION

Allelopathy is the injurious effect of one plant, microorganism, viruses, or fungi upon another surrounding species especially influencing the growth and development of agricultural and biological ecosystem [1]. This effect is due to the release of some biochemicals, known as allelochemicals which are the plant secondary metabolites. These biochemicals from the higher plant species (donor) generally deteriorate the growth and development of plumule and radical of the recipient surrounding species of plants by inhibiting seed germination through blocking hydrolysis of nutrients reserve and cell division [2, 3]. Allelochemicals mainly affect respiration, photosynthesis, cell division and enlargement, metabolicactivities, protein synthesis and enzyme actions of plants. Few plant growth inhibitors which later on identified and named as parthenin, caffeic acid and p-coumaric acid are primary inhibitors and were obtained from the stem tissue extract of the *Parthenium hysterophorus* L. [4, 5, 6].

Species of plants, animals or microorganisms that are not native to specific ecosystem are referred as invasive species. Invasive species have the capability of spreading fast as they have high competitiveness and ability to colonize new areas within short time periods. Some of the local invasive species such as *Parthenium hysterophorus* L. and *Eupatorium adenophorum* Spreng have similar allelopathic potential and affect invasively the growth of seeds of economically important crop plants such as wheat, maize and horse gram respectively. Invasive plants release certain novel allelochemicals into the invaded area. *Parthenium hysterophorus* L., a native to America, is an exotic invasive species belonging to family Asteraceae and is now spread in Asia and Africa [7]. It is commonly known as congress grass and is an annual herb with a deep taproot and an erect stem that become woody with age. *Parthenium hysterophorus* L.was accidently introduced to India through imported food grains and at present has occupied almost all parts of India [8]. The allelopathic nature of *P. hysterophorus* is due to water soluble phenolics and sesquiterpenes lactones in their roots, stem, leaves and seeds [9]. Due to its allelopathic effect, it is strongly competitive for soil moisture and nutrients [10]. The allelopathic grasses such as *Imperata cylindrica* (L). Beauv. and *Desmostachya bipinnata* Stapf. are effective in reducing the distribution of *Parthenium hysterophorus* L. [11, 12].

There are some reports on the effect of *P. hysterophorus*

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extract on the germination and growth of *Zea mays* from Manipur [1], *Triticum sativum* from Pakistan [4] and on the seedling growth of *Titricum sativum* from Uttarakhand [13]. To the best of our knowledge, no work has been done so far on the effect of *P. hysterophorus* extract on seed germination of Titricum *sativum* and seedling growth and biomass of *Zea mays* and *Macrotyloma uniflorum* from Uttarakhand. Therefore, the study has been undertaken to examine the allelopathic effect of *P. hysterophorus* and explore its toxic potential.

2) MATERIALS AND METHODS

Collection, identification and processing of experimental species

The study was conducted during the period of May to July 2016 at Department of Botany, D. S. B. Campus, Kumaun University, Nainital. This study was conducted to check the allelopathic effect of invasive species (*Parthenium hysterophorus*L.) extract on shoot and root growth of maize (*Zea mays* L.), wheat (*Triticum aestivum* L.) and horse gram (*Macrotyloma uniflorum* Lam.). All the species were identified by Prof. Y. P. S. Pangtey. *Parthenium hysterophorus* L. was collected from crop field of Haldwani, District Nainital, India at flowering stage. The whole plant was separated into two parts i.e. aerial and underground and then washed and chopped into small pieces. The aerial parts (AP) were oven dried at 60°C for 48 hours, whereas the underground parts (UP) were dried at 60°C for 60 hours to obtain constant weight. The oven dried plant parts were crushed to powder form for further analysis.

Extract preparation

Extracts were prepared by adding 200g of powdered plant material of (aerial and underground parts) in 2000mL of double distilled water and methanol and mixed for 24 hours in a horizontal rotator shaker. The extracts were filtered through filter paper (Whattman No.1) and dried on hot plate.

Collection of test crop seeds

The crop seeds were purchased from the market in healthy conditions at their maturity.

Evaluation of phytotoxic effect

The extracts of the aerial and underground parts of *P. hysterophorus* were used to test the phytotoxic effect on *Zea mays*, *Macrotyloma uniflorum* and *Triticum aestivum*. The extracts were taken at the different concentration (1mg mL^{-1},100mg mL^{-1},150mg mL^{-1} and 400mg mL^{-1}) for each extract i.e. double distilled water (DAP and DUP) and methanol (MAP and MUP). The germination of wheat, maize and horse gram were studied by pot method. Ten seeds of each crop were soaked overnight in the extracts of the above mentioned concentration. These soaked seeds were sown in the pots (10cm x 10cm) containing sterilized soil. The soil was continuously moist with double distilled water. The experiment was carried for 12 days an average temperature of 30°C. Growth and germination percentage were measured at the interval of six days. After this, the plants were uprooted and were oven dried at 46°C till constant weight for biomass. For evaluating the germination percentage, the following formula was used:

$$\text{Germination (\%)} = \frac{number of germinated\ seeds}{total\ number of seeds\ sown} X\ 100$$

Data Analysis

The data were subjected to one-way analysis of variance (ANOVA), and treatment means were compared at a significance level of $p \le 0.05$ by Duncan multiple range test. Statistical analysis was done with SPSS 18.0 for Windows statistical software package (SPSS, Chicago, IL, USA). The mean value of the seedling length was calculated along with standard deviation (SD) using MS-Excel.

3) RESULTS AND DISCUSSION

With increase in extract concentration, there was a gradual decrease in seedling length. The mean values of seedling length were observed maximum in the seeds treated with AP extract in comparison to the UP extract. Among the tested crops, *M. uniflorum* was the most sensitive species in terms of germination and growth inhibition followed by *T. aestivum* and *Z. mays*. Methanol extract showed better inhibitory effect as compared to the aqueous extract which was indicated by complete failure of germination and seedling growth at 100, 500 and 400 mg mL^{-1} concentrations.

Mean length

The data on the effect of double distilled water and methanol extracts on the growth of all the tested crops is shown in Figure 1 and Figure 2. In maize, the mean shoot length was ranged between 3.9cm- 17.6cm and mean root length was ranged from 4.2cm to 6.2cm in both DAP and DUP extracts at all concentrations. Whereas, in methanol fraction, the growth was noted only at 1mg mL^{-1} concentration.

The Mean length of horse gram shoot ranged between 3.2cm-8.3cm and root length was observed from 3.1cm to 4.3cm in DAP extract at all concentrations. Whereas in DUP extract, the mean length of shoot and root were found between 3.2cm-8.3cm and 2.8cm-4.2cm respectively (Figure 1& 2). The growth of horse gram was observed only at 1mg mL^{-1} concentration of MAP and MUP extracts.

For wheat, shoot and root mean lengths were found between 3.0cm-12.3cm and 3.3cm-5.4cm in both DAP and DUP extracts respectively. In MAP and MUP extract treated wheat, the growth was observed only 1mg mL^{-1}concentration (Figure 1& 2).

Germination percentage

The Germination percentage was found to be the highest for maize (80%) at 1 mg mL^{-1} concentration with DAP extract during 1-6th day observation followed by 50%, 40% and 20% at 100mg mL^{-1}, 150 mg mL^{-1} and 400 mg mL^{-1} concentration respectively. Similarly, percentage germination of horse gram at concentrations of 1 mg mL^{-1}, 100 mg mL^{-1}, 150 mg mL^{-1} and 400mg mL^{-1} was 70%, 40%, 30% and 10% respectively. Germination (%) of *T. aestivum* was recorded highest (80%) at 1mg mL^{-1} followed by 100 mg mL^{-1}, 150 mg mL^{-1} and 400 mg mL^{-1}concentrations. With underground part extract, the germination at concentration of 1mg mL^{-1}, 100mg mL^{-1}, 150mg mL^{-1} and 400mg mL^{-1} concentration was 70%, 40%, 40% and 10% for maize, 60%, 40%, 30% and 10% for horse gram and 60%, 30%, 30% and 10% for wheat respectively (Figure 3).

Germination observed in maize was 30%, in horse gram 20% and in wheat 20% only at 1mg mL^{-1} concentration of

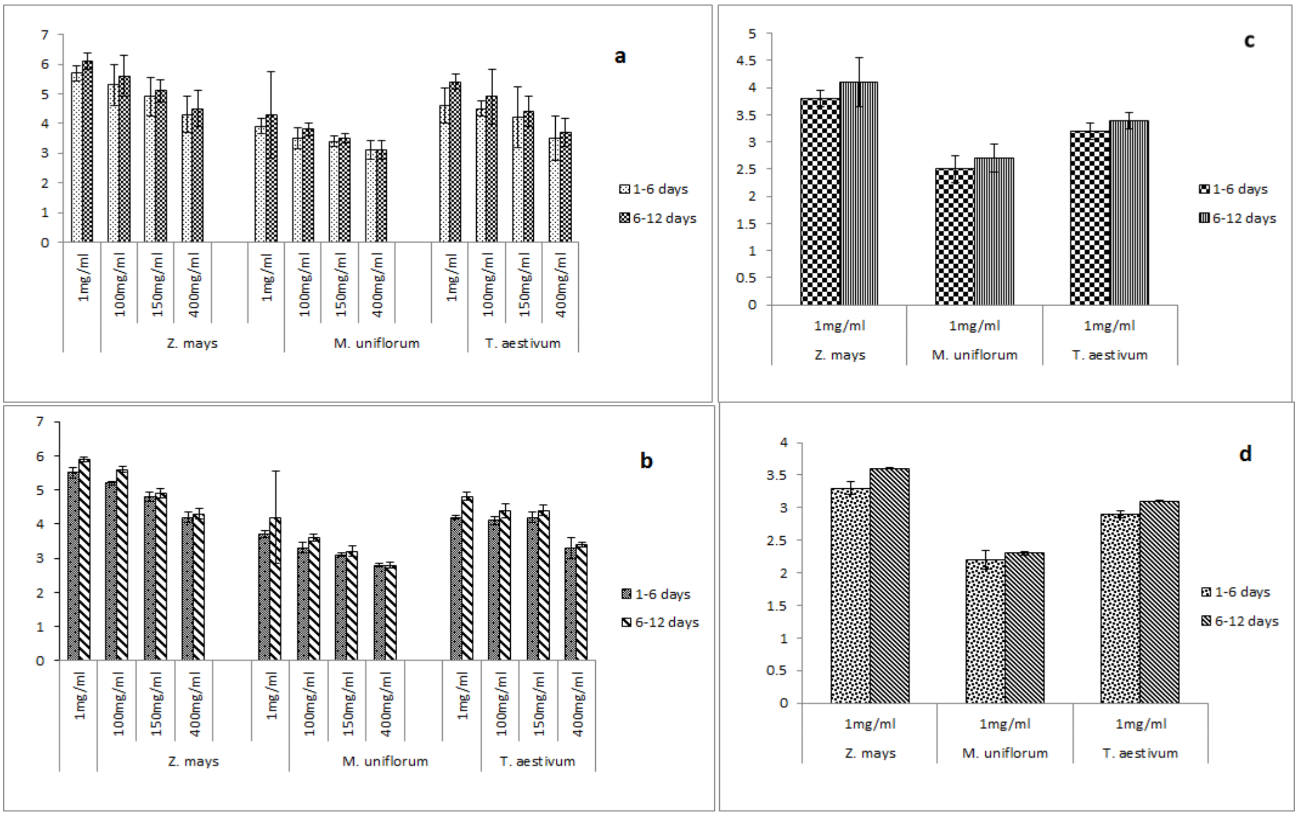


Figure 1: Mean root length of test crops in **a)** DAP; **b)** DUP; **c)** MAP and **d)** MUP extracts.

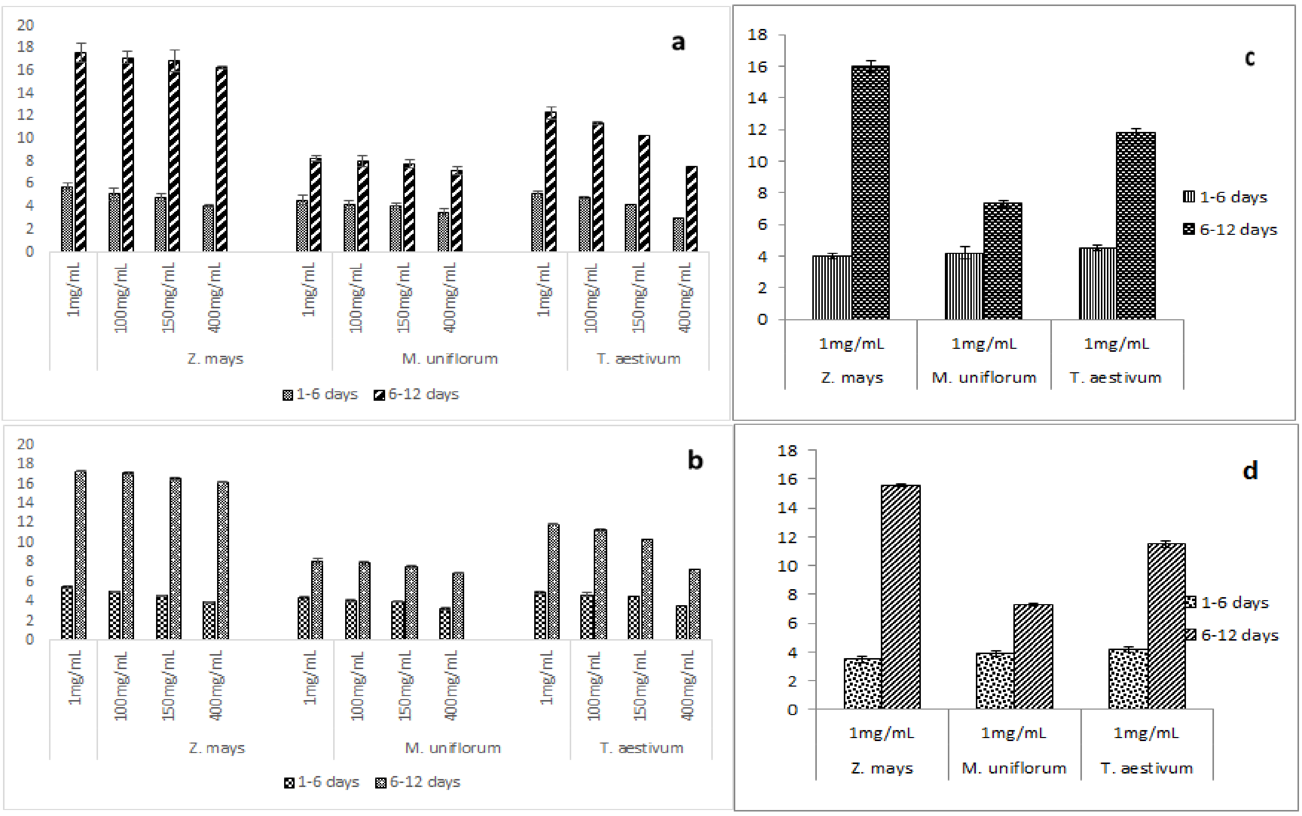


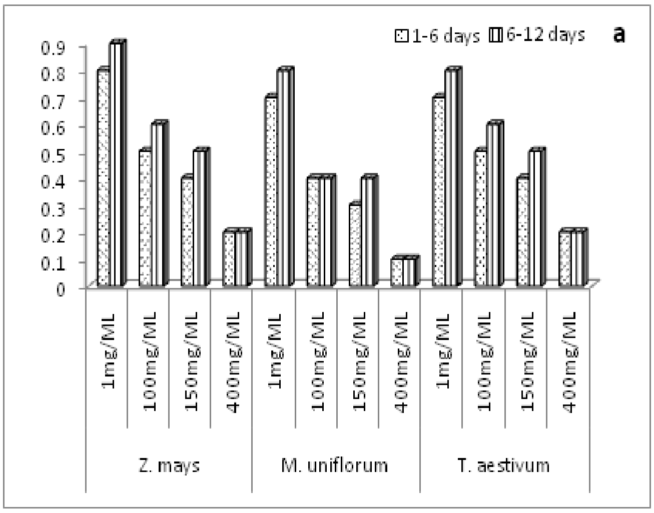
Figure 2: Mean shoot length of test crops in **a)** DAP; **b)** DUP; **c)** MAP and **d)** MUP extracts

MAP extract whereas; in the seeds treated with MUP extract, it was 20%, 20% and 10% in maize, horse gram and wheat respectively only at the concentration of 1 mg mL^{-1}.

During 6-12th days of experiment, for DAP extract, the germination percentage of maize at concentration of 1 mg mL^{-1}, 100 mg mL^{-1},150 mg mL^{-1} and 400 mg mL^{-1} was 90%, 60%, 50% and 20% respectively. The germination percent of horse gram at these concentrations was 80%, 40%, 40% and 10% respectively, whereas in wheat, these were recorded 80%, 60%, 50% and 20% respectively. With UAP, the germination (%) of maize at concentration of 1 mg mL^{-1}, 100 mg mL^{-1}, 150 mg mL^{-1} and 400 mg mL^{-1} was 80, 50, 40 and 20%

respectively, for horse gram it was observed to be 70, 50, 40 and 10% respectively while in wheat, 70, 40, 30, and 20% germination was recorded for the same concentrations (Figure 3).

MAP extract showed 50%, 30% and 40% of percent germination only at concentration of 1mg mL^{-1} for maize, horse gram and wheat respectively. Similarly, for MUP extract, the germination percentage for maize, horse gram and wheat was 40%, 20% and 30% which was observed only at concentration of 1mg mL^{-1}.



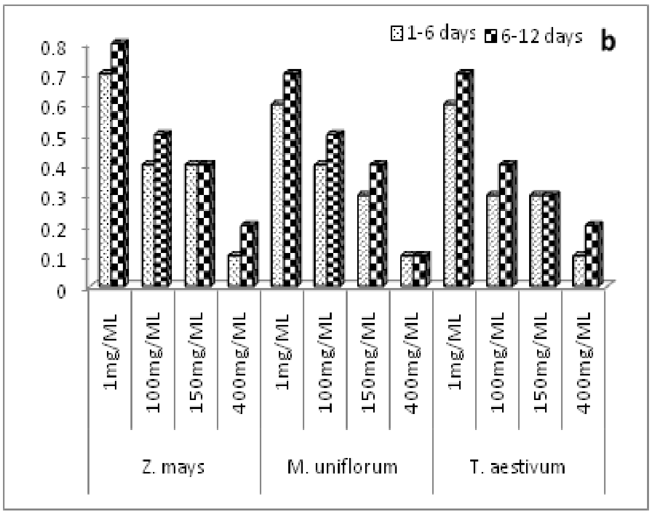


Figure 3: Germination (%) of test crops in **a)** DAP; **b**) DUP extracts.

Biomass

In DAP extract of *P. hysterophorus* L., the biomass of maize at concentration of 1 mg mL^{-1}, 100 mg mL^{-1}, 150 mg mL^{-1} and 400 mg mL^{-1} was 1.97, 1.68, 1.47 and 0.90 g respectively. Horse gram biomass at concentrations of 1 mg mL^{-1}, 100 mg mL^{-1}, 150 mg mL^{-1} and 400 mg mL^{-1} was 1.81, 1.53 1.28 and 0.84g respectively. The biomass of wheat at concentration of 1 mg mL^{-1}, 100 mg mL^{-1}, 150 mg mL^{-1} and 400 mg mL^{-1} was 1.89, 1.61, 1.35 and 0.88 g respectively. Similarly, in DUP extract, the biomass of maize at concentration of 1 mg mL^{-1}, 100 mg mL^{-1}, 150 mg mL^{-1} and 400 mg mL^{-1} was 1.91, 1.59, 1.47, and 0.90 g and for horse gram, it was 1.76, 1.47, 1.22 and 0.83g respectively. In case of wheat, the biomass at concentration of 1 mg mL^{-1}, 100 mg mL^{-1}, 150 mg mL^{-1} and 400 mg mL^{-1} was 1.85, 1.58, 1.31, and 0.87g respectively.

Whereas, with MAP extract, the biomass of maize, horse gram and wheat at concentration of 1 mg mL^{-1} was 1.57, 1.22 and 1.32 respectively similarly in MUP extract, horse gram and wheat, it was recorded to be 1.28, 1.01 and 1.19 g respectively.

A significant reduction in the germination, seedling growth and biomass was observed in test crops. From mean seedling length, germination and biomass data, *P. hysterophorus* L. was observed to be a harmful species and showed more strong inhibitory effect on the growth of horse gram than the other two test crops. This can attribute to the fact that *P. hysterophorus* L. leads to the habitat and ecosystem change by competing directly with native species [7, 14, 15].

A previous report suggested that extracts of aerial part of invasive species (*P. hysterophorus* L.) inhibited the germination and shoot growth of cabbage [16]. *Parthenium* residue extract which was rich in phenols showed strong phytotoxic effect on the growth of radish and chickpea and [5]. The allelochemicals are released through leachation or microbial decay and are water soluble [17]. The allelopathic potential vary from plant to plant [18, 19, 20, 21, 22, 23,] as was observed in horsegram, maize and wheat. Wakjira [24], Netsere and Mendesil [25], Demissie et al., [26] and Chopra et al. [27] studied the effect of root, shoot and leaf extracts on soyabean, haricot bean, onion, horse gram and maize which supports our observation. Singh et al. [28] have also reported inhibitory effect of *Parthenium hysterophorus* on the growth of cultivated species, cereal crops and wild species.

Qasem and Foy in 2001 reported that the residues of many weeds were known for the adversely affect to other plants through allelochemicals [29]. Furthermore, Mawal *et al*. in 2015 documented that many secondary metabolites are released from the root part, through which soil composition changes due to released allelochemicals [30].

The previous reports [31, 32] suggested that the root extract of *Parthenium* showed auto toxic effect at higher concentrations. Similarly, Dogra and Sood [33] pointed that the soil mixed with residues of the *Parthenium* had adverse effect on seed germination and seedling growth of the native plants of Himachal Pradesh.

The present study explains that *Parthenium hysterophorus* L. affects the growth of surrounding plants due to its growth inhibitory substances which released into the soil. The other biotic factors may also responsible for erratic growth of the other plants which enhance the effect of these noxious weeds with special response to growth.

4) CONCLUSION

The present study concluded that *Parthenium hysterophorus* L. extracts have inhibitory effect to reduce early growth of wheat, maize and horse gram. Methanol extract had the more inhibitory power as compared to the aqueous extract. This provides the evidence of allelopathic potential of *P. hysterophorus* root and shoot on agricultural production per annum. It can cause noxious effect on growth of crops. Therefore, it is necessary to control *P. hysterophorus* and these crops should be prevented from the contact of this weed.

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