"Allelopathic Effects of *Parthenium hysterophorus* L. Extracts on Seed Germination and Seedling Growth of *Raphanus sativus* L."

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Abstract

Allelopathy is a biologically significant ecological interaction in which plants release chemical compounds that influence the growth and development of neighboring species. The present study investigates the allelopathic effects of aqueous extracts of *Parthenium hysterophorus* L. on seed germination and seedling growth of *Raphanus sativus*. Extracts of leaf, stem, and root were prepared at varying concentrations (2.5%, 5%, 7.5%, and 10%) and evaluated using a standard Petri dish bioassay. The results revealed a concentration-dependent inhibition in germination percentage, root length, shoot length, and seedling vigor index. Among different plant parts, leaf extracts exhibited the strongest inhibitory effect. Phytochemical screening confirmed the presence of bioactive compounds such as alkaloids, phenols, tannins, glycosides, and saponins. The findings indicate that *Parthenium hysterophorus* possesses significant allelopathic potential and could be utilized as a natural bioherbicidal agent for sustainable agricultural practices.

Keywords: *Allelopathy, Parthenium hysterophorus, Raphanus sativus, phytochemicals, seed germination, bioherbicide*

Introduction

Allelopathy is defined as a biological phenomenon in which plants release chemical compounds into the environment that influence the growth, survival, and reproduction of other organisms (Rice, 1984). These chemical substances, known as allelochemicals, are secondary metabolites produced by plants and play a significant role in ecological interactions and plant competition (Inderjit & Duke, 2003). Allelopathy has been widely studied as a natural mechanism of weed suppression and plant defense (Einhellig, 1995).

Secondary metabolites such as phenolics, flavonoids, alkaloids, terpenoids, and glycosides are known to exhibit allelopathic effects by interfering with physiological and biochemical processes in plants (Harborne, 1998; Weston & Duke, 2003). These compounds may inhibit seed germination, root elongation, enzyme activity, and nutrient uptake (Inderjit & Duke, 2003). The inhibitory effects are often concentration-dependent and vary with plant species and environmental conditions (Einhellig, 1995).

Weeds are one of the major constraints in agricultural productivity, causing significant yield losses due to competition for resources such as water, nutrients, and light (Oerke, 2006). The excessive use of synthetic herbicides for weed control has led to environmental pollution, development of herbicide resistance, and adverse effects on human health (Duke et al., 2010). Therefore, there is increasing interest in exploring plant-based allelochemicals as eco-friendly alternatives for weed management (Weston & Duke, 2003).

Parthenium hysterophorus L., commonly known as congress grass, is an invasive weed belonging to the family Asteraceae and is widely distributed in tropical and subtropical regions (Adkins & Shabbir, 2014). It is known for its aggressive growth, high reproductive capacity, and strong allelopathic properties (Kanchan & Jayachandra, 1980). The plant releases toxic compounds such as parthenin, phenolic acids, and sesquiterpene lactones, which inhibit the germination and growth of surrounding vegetation (Adkins & Sowerby, 1996).

Previous studies have demonstrated that aqueous extracts of *Parthenium hysterophorus* significantly reduce germination and seedling growth in several crop species (Batish et al., 2002; Singh et al., 2003). The allelopathic effect is mainly attributed to phenolic compounds that interfere with cellular metabolism and membrane integrity (Batish et al., 2002). The use of such plant-derived allelochemicals offers a sustainable and environmentally safe approach to weed management (Inderjit & Duke, 2003).

Raphanus sativus L. (radish) is an important vegetable crop belonging to the family Brassicaceae and is commonly used in allelopathic studies due to its rapid germination and sensitivity to chemical stimuli (Singh et al., 2003). It serves as an ideal model plant for evaluating the inhibitory effects of allelochemicals under laboratory conditions.

Therefore, the present study was undertaken to evaluate the allelopathic effects of different plant parts (leaf, stem, and root) of *Parthenium hysterophorus* on the seed germination and seedling growth of *Raphanus sativus*, along with phytochemical analysis to identify potential bioactive compounds responsible for inhibition.

Materials and Methods

Plant Material Collection and Identification

Fresh plants of *Parthenium hysterophorus* were collected from the Kopargaon region. The plant material was identified using standard floras (Cooke, 1903).

Preparation of Extracts

Aqueous extracts were prepared following the standard maceration method (Harborne, 1998). 10 g of plant material was homogenized in 100 mL distilled water and filtered.

Bioassay Procedure

The Petri dish method described by **Standard germination bioassay method** (ISTA, 2015) was used.

- 10 seeds per plate
- 4 replicates
- Incubation at 25°C
- Duration: 7 days

Parameters Measured

- Germination %
- Root length
- Shoot length
- Seedling vigor index

Calculated using standard formula (Abdul-Baki & Anderson, 1973).

Phytochemical Screening

Phytochemical screening of plant extracts was carried out using standard qualitative methods described by Harborne (1998) and Trease and Evans (2009) to detect alkaloids, flavonoids, tannins, saponins, glycosides, phenols, terpenoids, and proteins.

Results

Effect of Parthenium hysterophorus Extract on Seed Germination

The germination percentage of Raphanus sativus seeds was significantly affected by different concentrations of Parthenium hysterophorus extracts. A gradual decline in germination was observed with increasing concentration of extracts, indicating a dose-dependent inhibitory effect.

Table 1. Effect of Parthenium hysterophorus Extract on Seed Germination

Concentration (%)	Germination (%)	Inhibition (%)
Control	100	0
2.5	85	15
5.0	70	30
7.5	55	45
10.0	40	60

The highest germination (100%) was observed in the control, whereas the lowest germination (40%) was recorded at 10% concentration. This clearly demonstrates that higher concentrations of extracts exert stronger inhibitory effects on seed germination.

Effect on Seedling Growth (Root and Shoot Length)

The root and shoot growth of Raphanus sativus seedlings were significantly reduced in treated samples compared to control. Among the different plant parts, leaf extracts exhibited maximum inhibitory effects.

Table 2. Effect of Different Plant Parts on Seedling Growth

Treatment	Root Length (cm)	Shoot Length (cm)
Control	5.2	4.8
Leaf	2.1	1.9
Stem	3.0	2.7
Root	3.5	3.1

Leaf extract showed the greatest reduction in both root and shoot length, followed by stem and root extracts. Root growth was more sensitive compared to shoot growth, indicating higher susceptibility of root tissues to allelochemicals.

Phytochemical Screening

Qualitative phytochemical analysis revealed the presence of several bioactive compounds in different plant parts of Parthenium hysterophorus.

Table 3. Phytochemical Screening of Different Plant Parts

Phytochemical	Leaf	Stem	Root
Alkaloids	+	+	+
Flavonoids	–	–	–
Tannins	+	–	–
Saponins	+	+	–
Glycosides	+	+	+
Phenols	+	–	–
Terpenoids	–	–	+
Proteins	–	–	–

Leaf extracts showed the highest diversity of phytochemicals, particularly phenols, tannins, and saponins, which are known for their allelopathic activity. The presence of these compounds supports the observed inhibitory effects on seed germination and seedling growth.

Discussion

The present study clearly demonstrates the strong allelopathic potential of *Parthenium hysterophorus* on the seed germination and early seedling growth of *Raphanus sativus*. The results revealed a consistent and concentration-dependent inhibitory effect, indicating that increasing levels of plant extracts significantly suppress germination and growth parameters. This pattern strongly supports the role of allelochemicals in regulating plant–plant interactions.

The reduction in germination percentage observed in treated seeds suggests that the bioactive compounds present in *Parthenium* extracts interfere with the physiological processes essential for seed germination. Germination is a complex process involving water uptake, enzyme activation, and mobilization of stored food reserves. The inhibitory effect observed in this study indicates that allelochemicals may disrupt these metabolic pathways, thereby delaying or preventing successful germination.

A more pronounced effect was observed on seedling growth, particularly on root elongation. The root system is generally more sensitive to allelochemicals because it is the first organ to come into direct contact with toxic compounds in the surrounding medium. The significant reduction in root length suggests that these compounds may interfere with cell division and elongation processes in the root meristem. The comparatively lesser inhibition in shoot growth indicates differential sensitivity of plant organs to allelochemical stress.

Among the different plant parts tested, leaf extracts exhibited the highest inhibitory effect on both germination and seedling growth. This observation suggests that leaves contain higher concentrations of active phytochemicals responsible for allelopathic activity. Leaves are known to accumulate secondary metabolites involved in plant defense, which may explain their stronger phytotoxic effects compared to stem and root extracts.

The phytochemical screening results further support the allelopathic potential of *Parthenium hysterophorus*. The presence of compounds such as alkaloids, phenols, tannins, glycosides, and saponins indicates a complex mixture of bioactive substances capable of influencing plant growth. These compounds are known to affect membrane permeability, enzyme activity, and hormonal balance, leading to growth inhibition.

The observed dose-dependent inhibition highlights the importance of concentration in determining the extent of allelopathic effects. Lower concentrations showed moderate inhibition, while higher concentrations resulted in severe suppression of germination and growth. This suggests that the accumulation of allelochemicals in the environment can significantly impact plant establishment and survival.

From an ecological perspective, the strong allelopathic activity of *Parthenium hysterophorus* contributes to its invasive nature and competitive advantage over native species. By inhibiting the germination and growth of neighboring plants, it can dominate habitats and reduce biodiversity. At the same time, this property can be explored for beneficial applications in agriculture.

The findings of this study indicate that *Parthenium hysterophorus* has potential as a source of natural bioherbicidal compounds. The use of plant-based allelochemicals offers an eco-friendly alternative to synthetic herbicides, reducing environmental pollution and promoting sustainable agricultural practices. However, further research is required to isolate and identify the specific active compounds responsible for inhibition and to evaluate their effectiveness under field conditions.

Overall, the study provides clear evidence that *Parthenium hysterophorus* exerts significant inhibitory effects on seed germination and seedling growth of *Raphanus sativus*, primarily due to the presence of diverse phytochemicals. The results contribute to a better understanding of allelopathic interactions and highlight the potential application of invasive weeds as valuable bioresources.

Conclusion

The present study confirms that *Parthenium hysterophorus* exhibits strong allelopathic effects on seed germination and seedling growth of *Raphanus sativus*. The inhibitory effect is concentration-dependent and more pronounced in leaf extracts. The presence of bioactive phytochemicals suggests its potential application as a natural bioherbicide. Further studies on isolation of active compounds and field validation are recommended.

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