Allelopathic Interactions of *Parthenium hysterophorous* with Kidney Bean, *Phaseolus vulgaris*

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Authors' contributions

This work was carried out in collaboration between both authors. Author HMT designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author JMA wrote the protocol, carried out the experiments and recorded that data. Both authors read and approved the final manuscript.

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ABSTRACT

Allelopathy, an important mechanism in invasive species stems from the lack of coevolved tolerance of indigenous species to novel chemicals released by the invader species. These chemicals are key to successful invasive of species of natural plant communities and ecosystems. This study analyzed the allelopathic effects of the invasive plant, *Parthenium hysterophorous* on the growth of kidney beans (*Phaseolus vulgaris*). One hundred and fifty viable kidney bean seeds were washed in distilled water, and transferred in triplicates to pots with wet sterile sand. Ten grams of freshly collected Parthenium leaves and roots were weighed, ground separately using a mortar and a pestle, mixed with 100 ml of distilled water in a beaker and left for 24 hours in a dark at a room temperature (25°C). The aqueous extract filtrates were used in experimental treatments. While untreated (control) seeds germinated on day 4 seeds treated with leaf extract germinated on day 14 and day 9 for the root extract. Leaf extract inhibited germination and sprouting of new leaves more effectively than root extract. Leaves in control seeds appeared on day 1 after...
In treated seeds, leaves appeared on the 4th day then stagnated until day 15 when more leaves sprouted. Root extract significantly depressed seed germination. The number of new leaves increased significantly in control seedlings compared to the treated ones. Additionally, combined treatment with root and leaf extracts significantly inhibited shoot growth, and the increase in leaf length and width. A comparison of the effectiveness of the root and leaf extracts showed that leaf extract was more effective in inhibiting shoot growth and leaf width than the root extract.

Keywords: Allelopathy; parthenium; beans; germination; extracts.

1. INTRODUCTION

*Parthenium hysterophorous* is an annual herb of the family Asteraceae and is an aggressive colonizer [1]. This herb has its origins in North America [2,3] and currently, its invasion has become pandemic [4]. In Africa, it was first reported in southern Africa in the 1880s from where it has spread to most parts of the continent. In Kenya, it has become, a serious invasive weed especially along newly constructed roads and surrounding farmlands [5].

*P. hysterophorous* is considered a noxious invasive weed and is known to have harm crops, ecosystems, animals, humans, and biodiversity [6,7,8,9]. It produces secondary chemicals that exert strong allelopathic effects on different plant species [10,11,12] and animals [13]. The success of this weed is dependent on out-competing other species for resources; which ultimately, disrupts the functioning of natural ecosystems [14,15,16]. A chemical compound ‘parthenin’ produced by the weed inhibits germination and root growth in crops [17,18,19]. It also interferes with nitrifying nitrogen-fixing bacteria in leguminous plants thereby negatively affecting nitrogen fixation leading to a decline in agricultural crop yields and consequently, food insecurity. Food security is among the Kenyan government big four agendas towards the achievement of the vision 2030 [20].

This study sought to determine the effects of *Parthenium hysterophorous* leaves, roots and combined extract of leaves and roots on kidney bean growth. Being widespread in Kenya, *P. hysterophorous* often occurs as a dense monocultural colony on roadsides and the nearby farms. Kidney beans were chosen because of its high value as source of food to humans and is rich in protein.

The findings of this study will create awareness of problems and effects of *P. hysterophorous* on crop yields, livestock and man. Outcomes of this study also will be useful to people whose farms, fallowed lands and flood plains have been invaded by this toxic invasive weed.

2. METHODS

The study was carried out in the Botany laboratory of Jaramogi Oginga Odinga University of Science and Technology in Bondo, Siaya County. The university lies between longitudes of 31°32'0" E-31°57'0" W and latitudes of 0°07'30" N-0°10'15" S of the equator at an altitude of 1440 m above sea level [21]. Bondo is characterized by high temperatures, low rainfall with high evaporation rates and lies within the lower midland agro-ecological zone [22].

2.1 Study Design

Fresh plant parts including leaves and roots of *P. hysterophorous* were picked randomly from the roadsides and fallow lands within the university and its vicinity. The collected plants were brought to the laboratory for sample processing. Experimental kidney bean seeds were picked randomly from Bondo market, and were kept under room conditions, in Botany laboratory.

2.2 Planting of the Kidney Bean Seeds

Twelve (12) viable kidney beans were washed in distilled water, and transferred in triplicates to pots half-filled with well-watered wet sterile sand. Each seed was planted in a concentric hole 2 cm apart. The pots were placed near a sunlight source and maintained at optimal temperature (25°C) and moisture. The seeds were watered twice a day; in the morning and in the evening using 100 ml of distilled water to ensure plenty supply of moisture, necessary for germination.
2.3 Preparation of Aqueous Extracts

Ten (10) grams of freshly collected *Parthenium* leaves were weighed using a weighing balance and grounded using a mortar and pestle. This was mixed with 100 ml of distilled water in a beaker and left to stand for 24 hours in a dark room at room temperature (25°C). The aqueous extract was obtained as filtrate of the mixture, after which it was sprinkled around the germinating bean seeds every 5 days. Its effects on the germination and growth of seedlings observed and recorded.

Five (5) grams of freshly collected leaves and 5 g of freshly collected roots were weighed simultaneously, grounded in a mortar to finer mash and was transferred to a beaker where it was mixed with 100 ml of distilled water in a dark room and left to stand for 24 hours at 25°C. The filtrate was applied on germinating seeds by every 5 days. The experiment was left to run for 28 days and on the 29th day the shoot growth, leaf length and width and the number of leaves of the seedling were recorded. A control set up of kidney bean seeds free from the weed aqueous filtrate was prepared and planted. Observations on number of leaves were taken every 2 days.

3. RESULTS

3.1 Effects of *Parthenium Hysterophorous* Leaf Extract on the Bean Growth

3.1.1 Effects on duration of germination and number of new leaves

Fig. 2 shows results of the effects of *Parthenium hysterophorous* leaf extract on the number of days to germination and the number of leaves over a 21-day period. Leaf extract significantly inhibited seed germination and the number of new leaves. While untreated seeds germinated on the 4th day, treated seeds germinated on the 14th day. In addition, leaves in the control appeared on the 1st day after germination, while in treated seeds, leaves appeared on the 4th day and there were no new leaves until the 15th day.

3.1.2 Effects of Root Extract on Length of Germination and number of new Leaves

Root extract significantly inhibited seed germination, but had relatively insignificant effects on sprouting of new leaves (Fig. 3) over a 21-day period. Control seeds germinated by the 4th day, while the treated seeds germinated on
the 9th day. There were significant differences in the number of new leaves between treated seeds and the control (Fig. 3).

3.1.3 Effects of combined Root and Leaf Extract on Length of Germination and number of new Leaves

Results of combined root and leaf extracts show a highly significant inhibition of seed germination (Fig. 4). In addition, the number of new leaves was significantly reduced by the application of combined extracts.

When the effects of the root, leaf and root and leaf extracts were compared, it was clear that leaf extract was more effective in inhibiting germination and new leaves in bean plants than the roots (Fig. 5) followed by the roots extract.

Fig. 2. Effects of leaf extract on days to germination and number of new leaves

Fig. 3. Effects on root extract on length of germination and new leaves
3.2 Effects of Parthenium Hysterophorous Leaf Extract on the Kidney Bean Plant Growth

3.2.1 Effects of leaf extract on bean shoot and leaves

Fig. 6 show the effects of leaf extracts on shoot growth and new leaves. Leaf extract effectively inhibited the growth of the shoot and the length and width of leaves.

3.2.2 Effects of Root Extracts on bean height and leaves

Results of the root extracts treatment show that root extract was more effective in inhibiting leaf length and width (Fig. 7). Root extract also inhibited the growth of shoots.
3.2.3 Effects of both leaf and root extracts on bean plant growth

Combined treatment with root and leaf extracts revealed a significant inhibition of shoot growth, increase in leaf length and completely inhibited leaf width (Fig. 8).

A comparison of the effects of the root and leaf extracts showed that the leaf extract was more effective in inhibiting shoot growth and leaf width than the root extract (Fig. 9).

4. DISCUSSION AND CONCLUSIONS

Results showed that *P. hysterophorous* leaf extracts clearly delayed germination by more than 10 days in treated seeds of kidney bean. Similarly, root extracts of *P. hysterophorous* significantly inhibited bean growth, while combined extracts of the roots and leaves had far reaching effects on bean plant growth. These findings clearly show that allelochemicals inherent in *P. hysterophorous* significantly inhibited seed germination, shoot length.
elongation and leaf sprouting in kidney bean plants. The use of allelochemicals by invasive species has been reported in a number of studies. [23] & [24] reported that the successful invasions by the species Psidium guajava (common guava) of ecosystems could partially be explained by the allelochemicals that inhibit germination, growth and survival of conspecifics. Some of the active allelochemicals have been identified as terpenoids, coumarins, cyanogenic acids, flavonoids among others [25]. These allelochemicals are known to inhibit seed germination and growth by blocking nutrient uptake and interfering with cell division, consequently, inhibiting germination [25].

Most of allelochemicals in invasive species have been reported to interfere with hormone function and impairment of metabolic functions [25,26]. Changes in metabolism instigated by allelochemicals may additionally, suppress shoot and root length elongation [27]. [28] reported that the ability of some plant species to secrete oxalate, mitigated the effects of allelochemicals in elongation of the shoot and root such as in Markhamia lutea and Diospyros mespiliformis. These inhibitory effects appear to be concentration dependent and different species responded differently to the extracts [29,30,31].

![Combined Root and Leaf Extracts](image)

Fig. 8. Combined effects of root and leaf extracts on bean height and leaves (Exp. L is the leaf extract; Exp. R the root extract)

![Comparison of the effects of Root and Leaf extracts](image)

Fig. 9. Comparison of the effects of the root and leaf extracts
In conclusion, results from this study reveal that the success of *Parthenium hysterophorus*, could be attributed partly to its allelopathic potential that drive the invasive powers [32]. The fact that leaves, and roots both exhibited highly inhibitory effects on the kidney bean plants suggests a uniform distribution of allelochemical in the plant body. The inhibitory effects on seed germination, root and shoot elongation was concentration dependent, where an increase in concentration caused an increase in inhibition [33,34].

Further Scientific studies are recommended to determine the active allelochemical responsible for their invasive success [30,31,35].

**COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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