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Research Article

Population dynamics of *Parthenium hysterophorus* (Asteraceae) and its biological suppression through *Cassia occidentalis* (Caesalpiniaceae)

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Abstract: Phytosociological analysis performed over 2005 to 2009 revealed that *Cassia occidentalis* L. is a dominant species at 3 of 4 sites in Agra district, India, that were previously observed to be dominated by heavy populations of *Parthenium hysterophorus* L. In order to determine the role of biomolecular interaction, i.e. the allelopathic effect, if any, on this shift of floral pattern effects, aqueous shoot and root cold leachates were determined on seed germination, shoot cut bioassay, seedling bioassay, chlorophyll, nitrogen, and protein content of *P. hysterophorus*. A significant reduction in germination percentage, shoot cut bioassay, seedling bioassay, and chlorophyll of *P. hysterophorus* was noticed at higher concentration of shoot leachates. Root leachates of 100% concentration of *C. occidentalis* obtained after 9 days were responsible for the maximum inhibition of nitrogen percentage and protein content of *Parthenium*, indicating that biomolecular interaction plays a significant role in curbing the population dynamics of this obnoxious weed with enormous seed production potential.

Key words: Allelopathy, bioassay, botanic agent, chlorophyll, invasive species, nitrogen, phytosociology, protein

Introduction

In weed biological control programmes, evaluations of the effectiveness of biological control agents are often focused on the subjective assessment (Crawley, 1989) of the performance of biocontrol agents or on effects at a plant level (McClay, 1995). *Parthenium hysterophorus* L. (Asteraceae) is an annual herb of neotropical origin that now has a pantropical distribution. It was first reported in India in the late 1950s in Pune and is also known as "congress grass". It has achieved major weed status in India within a relatively short period of time. Although the weed is found mostly in wastelands, it also grows well in cultivated fields, pastures, and along roadsides. It forms pure stands at the expense of other vegetation, adversely affecting the species diversity of a region and also crop yield, animal husbandry, and human health (Kohli & Rani, 1994; Evans, 1997). *Parthenium* is an annual or short-lived ephemeral herb known for its vigorous growth (Paul & Knox, 2007). The adult phase is erect, much branched in its extremities, growing up to 1.5 m in height, though occasionally reaching 2 m in deep rich soil, stem greenish hairy, octangular, and longitudinally grooved (Dhawan & Dhawan, 1995a). The plant starts flowering about a month after germination and keeps growing throughout the year under optimum conditions (Ramaswami, 1998). A fully grown plant can produce more than 15,000 capitula in its lifetime, with each capitulum bearing 4 or 5 seeds. It is estimated that yield declines of 50%-55% in agricultural crops (>5-10 million rupees per annum) and a 90%-92% reduction in forage production (1-2 million rupees per annum) has been caused by *Parthenium* in India. Prolonged skin contact with *Parthenium* can result in allergenic eczematous contact dermatitis

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(AECD), whilst inhalation of the pollen can cause allergenic rhinitis, which can develop into bronchitis or asthma if the pollen enters the respiratory tract when breathing through the mouth; the mechanism involved has been documented by Towers and Subba Rao (1992). *Parthenium* dominance may possibly be due to some biochemical interference or biomolecular interaction along with its heavy seed output that gives it an additional advantage over native plants. This is further supported by a recently proposed hypothesis highlighting allelopathy as a novel strategy for the invasion of alien environments (Heirro & Callaway, 2003).

Cassia occidentalis L., more commonly known as "coffee weed", belongs to the family Caesalpiniaceae. It is an erect, shrub. The leaves are pubescent and are 3 to 6 cm long. The inflorescence is an axillary cyme. The flowers are purplish and its flowering time is from July to September. The fruit is a legume. *Cassia* plants are well known for containing a group of chemicals with strong laxative effects called anthraquinones. The most widely used species of *Cassia* in herbal medicine is known as senna (*Cassia senna* L. or *C. acutifolia* L.). The actions of anthraquinone chemicals are the basis of senna's widespread use as a purgative and strong laxative, while fedegoso (a chemical derived from *Cassia*) does contain a small amount of these anthraquinones. The main plant chemicals in fedegoso include: achrosine, aloe-emodin, anthraquinones, anthrones, apigenin, aurantiobtusin, campesterol, cassiollin, chryso-obtusin, chrysophanic acid, chrysarobin, chrysophanol, chrysoeriol, emodin, essential oils, funiculosin, galactopyranosyl, helminthosporin, islandicin, kaempferol, lignoceric acid, linoleic acid, linolenic acid, mannitol, mannopyranosyl, matteucinol, obtusifolin, obtusin, oleic acid, physcion, quercetin, rhamnosides, rhein, rubrofusarin, sitosterols, tannins, and xanthorin (Kudav & Kulkarni, 1974). In nature, *Cassia* competes well with *Parthenium* and inhibits its growth. Therefore, this study was performed to determine the cumulative effects of *C. occidentalis* on the seed germination, growth, and biological activities of *Parthenium* and to evaluate the allelopathic potential of this plant in suppressing *Parthenium hysterophorus.*

Materials and methods

Collection of data: Data on different parameters were collected at 4 different sites over 5 years. To conduct a plant census, a quadrat of 1 m^2 in size was laid at random. Likewise for basal area measurements, the circumference/diameter of the arborescent members was recorded in the field with the help of a measuring tape and foot rule.

Analysis of data: After collecting the field data, parameters like relative frequency, relative density, relative dominance, basal area, and the Importance Value Index (IVI) of species were calculated by using the formulae given below (Oosting, 1958; Phillips, 1959; Hanson & Churchill, 1961).

1. Relative frequency = $\dfrac{\text{Frequency of the species in x}}{\text{Sum of the frequency for all species in stand x}} \times 100$

2. Relative density = $\dfrac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$

3. Relative dominance = $\dfrac{\text{Total basal area of the species in all the quadrats}}{\text{Total basal area of all the species in all the quadrats}} \times 100$

4. Average basal area = $\sum \pi r^2/N$

5. Total basal area of species (sq. mm/sq.m) = Average (sq.mm) × $\dfrac{\text{Number of individuals per quadrat}}{\text{Size of quadrat (sq.m)}} \times 100$

6. Importance value index (IVI) of species = Relative frequency + Relative density + Relative dominance

7. S-W Index (Diversity Index) = The Shannon-Weaver Index, $\bar{H}$ involves log transformations as follows:

$$\bar{H} = \sum P_i \log P_i \quad (P_i = \frac{n_i}{N})$$

where P_i is the proportion of the individuals belonging to the ith species (Shannon & Weaver, 1949).

Preparation of aqueous leachates: The upper parts of shoot and root tips were collected from *C. occidentalis*; 100 g of shoot and root tips were soaked in 500 mL of double distilled water each under aseptic conditions for 3, 6, and 9 days and placed in conical flasks in a refrigerator at 8 °C. The aqueous leachates were filtered through three layers of muslin cloth/ cheese cloth to remove debris. The filtrate was then re-filtered through one layer of Whatman No.1 filter paper. Leachates of 50% and 100% concentration were prepared with sterilised distilled water and used for bioassay.

Seed germination: *Parthenium* seeds were collected and then selected using a stereomicroscope. The selected seeds were thoroughly washed with tap water to remove dirt and dust and then rinsed with mild detergent solution for 5-7 min. The seeds were surface sterilised with 0.1% $HgCl_2$ for 10 min and again washed with sterilised distilled water 4-7 times. The seeds were divided into 10 replicates of 10 seeds each in treated and untreated lots. Treated seeds were first soaked in 50% and 100% shoot and root leachates for 6 h in a 10 mL allelochemical solution and then placed on filter paper moistened with distilled water. Untreated weed seeds were placed on filter paper moistened with 10 mL of 50% and 100% shoot and root leachates. All the seed lots were allowed to germinate in 5” (12.7 cm) petri dishes, which were sealed with laboratory film (Parafilm) and placed in a germination incubator with a 25/20 ± 2 °C (13/11 h) temperature regime and a 13 h photoperiod (20 mmol m^{-2} s^{-1} photosynthetic photon flux density) and kept undisturbed for 30 days. Control samples received distilled water.

Shoot cut bioassay: Shoots of *Parthenium* (5 cm) with 1 or 2 inflorescences were taken. The inflorescences were washed in tap water. Then they were dipped in 1% sodium hypochlorite (NaOCl) solution for 3 min. The tips of the shoots were immediately washed in sterilised distilled water to remove any residual trace of the chemical.

An inclined cut was made at the tip and the shoots were placed in test tubes containing 10 mL of shoot and root leachates of 50% and 100% concentrations. The test tubes were sealed with cotton buds and aluminium foil to make them airtight. The effect of the leachates was observed after 24, 48, and 72 h at room temperature. Phytotoxic damage was recorded on the basis of a rating scale of 0-5, where 0 = no effect, 1 = slight chlorosis / lower leaf drops, 2 = marked chlorosis and slight necrosis, 3 = acute chlorosis and marked necrosis / drooping of entire twigs, 4 = falling of flowers and leaves / high necrosis and chlorosis, and 5 = acute chlorosis and very high necrosis leading to death of the whole shoot.

Seedling bioassay: *Parthenium* seedlings were raised in plastic pots containing sterilised soil, sand, and peat (1:1:1) and placed at room temperature 25 ± 1 °C. These seedlings were sprayed with shoot and root leachates of 50% and 100% concentrations. Observations regarding the toxicity of the seedlings were made after 24, 48, and 72 h. Phytotoxic damage was recorded on the basis of rating scale of 0-4; where 0 = no effect, 1 = slight chlorosis, 2 = marked chlorosis, 3 = drooping of seedlings, and 4 = death of seedlings.

The chlorophyll content of *Parthenium hysterophorus* was analysed by Arnon’s method (1949). Total nitrogen was analysed by following the method of Snell and Snell (1955).

Statistical analysis: All experiments were replicated 10 times and conclusions were drawn from the data on the basis of 2-way analysis of variance (2-way ANOVA). The calculated values were compared with tabulated values at a 5% level of significance. All analysis was conducted using Indostat software (Indostat Pvt. Ltd., India).

Results

Of the total flora studied, different species exhibited different competitive abilities. Among all the weeds, *Cassia occidentalis* showed the strongest competitive ability against *Parthenium* (Table 1). Data recorded in Table 1 show that at Site III *Parthenium* was a dominant species having a number of 70 individual species, closely followed by *Cassia,* which was 46 in number. At Site I, II, and IV *Cassia occidentalis* was a dominant species having a value of 32, 48, and 42 against *Parthenium,* which was only 12, 13, and 28 in number. The highest sociability of *Parthenium* was observed at Site III and the relative frequency, relative density, relative dominance, and IVI of *Parthenium* at Site III was found to be 31.25, 53.84, 46.10, and

Table 1. Phytosociological analysis of *Parthenium hysterophorus* and associated flora.

Site	Name of plant	Total number of individual species	Total number of quadrats in which species occur	Total number of quadrats studied	Frequency (%)	Density	Abundance	Relative frequency	Relative density	Relative dominance	IVI*	S-W Index**
I.	*Parthenium hysterophorus*	12 ± 0.5	6 ± 0.0	10 ± 0.0	60 ± 1.1	1.2 ± 0.1	2 ± 0.9	21.42 ± 0.4	19.04 ± 0.3	33.43 ± 1.4	73.89 ± 1.3	1.2755 ± 0.0
	Calotropis procera	13 ± 0.6	7 ± 0.0	10 ± 0.0	70 ± 0.0	1.3 ± 0.1	1.8 ± 0.1	25 ± 0.2	20.63 ± 0.4	13.37 ± 1.9	59 ± 1.9	
	Cassia occidentalis	32 ± 0.7	9 ± 0.0	10 ± 0.0	90 ± 1.0	3.2 ± 0.1	3.5 ± 0.9	32.14 ± 0.1	50.79 ± 0.1	44.61 ± 1.0	127.54 ± 1.2	
	Chenopodium album	3 ± 0.0	3 ± 0.0	10 ± 0.0	30 ± 0.8	0.3 ± 0.0	1 ± 0.5	10.71 ± 0.2	4.76 ± 0.5	5.59 ± 1.2	21.06 ± 1.4	
	Withania somnifera	3 ± 0.0	3 ± 0.0	10 ± 0.0	30 ± 0.7	0.3 ± 0.0	1 ± 0.5	10.17 ± 0.3	4.76 ± 0.5	2.98 ± 1.1	18.45 ± 1.5	
II.	*Parthenium hysterophorus*	13 ± 0.6	6 ± 0.0	10 ± 0.0	60 ± 1.0	1.3 ± 0.1	2.1 ± 0.8	18.18 ± 0.3	14.60 ± 0.2	18.54 ± 0.9	51.32 ± 1.2	1.2842 ± 0.0
	Cassia occidentalis	48 ± 0.2	10 ± 0.0	10 ± 0.0	100 ± 0.0	4.8 ± 0.0	4.8 ± 1.0	30.30 ± 0.1	53.93 ± 0.1	47.52 ± 0.9	131.75 ± 0.9	
	Calotropis procera	7 ± 0.0	6 ± 0.0	10 ± 0.0	60 ± 0.0	0.7 ± 0.0	1.1 ± 0.1	18.18 ± 0.3	7.86 ± 0.2	6.96 ± 1.0	33 ± 1.2	
	Datura stramonium	5 ± 0.0	4 ± 0.0	10 ± 0.0	40 ± 0.8	0.5 ± 0.0	1.2 ± 0.4	12.12 ± 0.3	5.61 ± 0.2	5.71 ± 1.2	23.44 ± 1.2	
	Croton bonplandianum	16 ± 0.1	7 ± 0.0	10 ± 0.0	70 ± 0.6	1.6 ± 0.1	2.2 ± 0.9	21.21 ± 0.3	17.97 ± 0.3	21.24 ± 1.0	60.42 ± 1.0	
III.	*Parthenium hysterophorus*	70 ± 0.4	10 ± 0.0	10 ± 0.0	100 ± 0.0	7 ± 0.0	7 ± 0.0	31.25 ± 0.1	53.84 ± 0.2	46.10 ± 1.2	131.19 ± 1.0	1.0464 ± 0.0
	Cassia occidentalis	46 ± 0.2	8 ± 0.0	10 ± 0.0	80 ± 0.9	4.6 ± 0.0	5.7 ± 0.0	25 ± 0.2	35.38 ± 0.2	44.66 ± 1.0	105.04 ± 1.0	
	Datura stramonium	3 ± 0.0	3 ± 0.0	10 ± 0.0	30 ± .2	0.3 ± 0.0	1 ± 0.5	9.37 ± 0.2	2.30 ± 0.2	3.24 ± 1.5	14.91 ± 1.1	
	Croton bonplandianum	8 ± 0.0	8 ± 0.0	10 ± 0.0	80 ± 0.2	0.8 ± 0.0	1 ± 0.6	25 ± 0.2	6.15 ± 0.2	4.53 ± 1.6	35.68 ± 0.8	
	Calotropis procera	3 ± 0.0	3 ± 0.0	10 ± 0.0	30 ± 0.6	0.3 ± 0.0	1 ± 0.6	9.37 ± 0.2	2.30 ± 0.2	1.45 ± 1.2	13.12 ± 0.7	
IV.	*Parthenium hysterophorus*	28 ± 0.1	9 ± 0.0	10 ± 0.0	90 ± 1.0	2.8 ± 0.0	3.1 ± 0.6	32.14 ± 0.2	35 ± 0.3	49.57 ± 0.9	116.71 ± 1.0	1.0497 ± 0.0
	Calotropis procera	6 ± 0.0	6 ± 0.0	10 ± 0.0	60 ± 0.9	0.6 ± 0.0	1 ± 0.5	21.42 ± 0.2	7.50 ± 0.4	8.05 ± 1.0	36.97 ± 1.5	
	Cassia occidentalis	42 ± 0.1	9 ± 0.0	10 ± 0.0	90 ± 1.0	4.2 ± 0.1	4.6 ± 0.0	32.14 ± 0.3	52.50 ± 0.2	31.65 ± 0.8	116.29 ± 0.9	
	Solanum nigrum	4 ± 0.0	4 ± 0.0	10 ± 0.0	40 ± 0.9	0.4 ± 0.1	1 ± 0.5	14.28 ± 0.3	5 ± 0.3	10.71 ± 0.9	29.99 ± 0.8	

n = 10; Mean ± Standard Error; *Importance Value Index; **Shannon-Weaver Index

131.19, respectively followed by *Cassia* having sociability of 25.00, 35.38, 44.66, and 105.04. Out of the four sites, three sites had *Cassia* as a dominant species with a maximum sociability of 30.30, 53.93, 47.52, and 131.75 versus *Parthenium,* which had only 18.18, 14.60, 18.54, and 51.32 sociability at Site II.

A remarkable thing was observed at Site IV. Although the individuals of *Cassia* were higher in number (42 versus *Parthenium*'s 28), the IVI of *Parthenium* was still higher (116.71) than *Cassia* (116.29). This was because the basal area covered by *Parthenium* was greater than that of *Cassia,* making its coverage area greater, and therefore the IVI of *Parthenium* was 0.42 greater than that of *Cassia*. Observations from Table 1 show that with the increase in the IVI of *Parthenium*, the S-W index (Diversity index) decreased or there was an inverse relationship between them. The highest S-W index was observed at Site II (1.2842), and here the IVI of *Parthenium* was at its lowest at 51.32. However, at Site III the highest IVI of *Parthenium* was observed (131.19) with the lowest S-W index value (1.0464).

In laboratory bioassay, the treatment of *Parthenium seeds* with shoot and root leachates of *C. occidentalis* exhibited marked significant variation ($P < 0.05$) in germination percentage over the control group. A total of 90% of seeds germinated with a G.V.I. of 3.85 in the control group. Untreated seeds soaked with 100% concentrations of *C. occidentalis* shoot leachates caused maximum inhibition (100%) in germination% and G.V.I, followed by those soaked in 50% concentrations, in which 20% and 0.85 germination% and G.V.I. was observed, respectively (Table 2). Minimum inhibition in germination percentage and G.V.I. was observed in 50% concentrations of treated and untreated *Parthenium* seeds by root leachates of *C. occidentalis,* i.e. 80% and 3.42, respectively, of *P. hysterophorus* (Table 2) and was found to be non-significant ($P > 0.05$).

In shoot cut bioassay, exposure to 9 day shoot leachates of *C. occidentalis* after 72 h increased the damage severity (3.00 on the rating scale), the symptoms mainly being characterised as chlorosis, necrosis, drooping, and eventually the death of plants in 100% concentrations, followed by root leachates in which 2.33 damage severity on the rating scale was observed in 50% and 100% concentrations of 9 day root leachates of *C. occidentalis* after 72 h (Table 3). However, no inhibition was observed when treated with 3 day root leachates after 24 and 48 h.

In seedling bioassay, visible symptoms were observed after 24 h. The spraying of shoot and root

Table 2. Effect of *Cassia occidentalis* on germination percentage and germination velocity index of *Parthenium hysterophorus*.

		Concentration	Germination (%)	G.V.I.
Control			90 (9.48)	3.85 (1.96)
Shoot	Treated seeds	50%	60*(7.74)	2.57*(1.60)
		100%	40*(6.32)	1.71*(1.30)
	Untreated seeds	50%	20*(4.47)	0.85*(0.92)
		100%	0*(0.00)	0*(0.00)
Root	Treated seeds	50%	80 (8.94)	3.42 (1.84)
		100%	60* (7.74)	2.57*(1.60)
	Untreated seeds	50%	80 (8.94)	3.42 (1.84)
		100%	40*(6.32)	1.71*(1.30)

n = 10; Values within parentheses are square root transformed values; *Significant at 5% level leachates of *C. occidentalis* on *Parthenium* seedlings produced visible chlorosis, drooping, and seedling death. The maximum inhibition of *Parthenium* seedlings was observed in 100% concentrations of 9 day shoot leachates of *C. occidentalis* after 48 h, i.e. 4.00 on the rating scale. A minimum inhibition in toxicity was observed in 50% and 100% concentrations of 3 day, 6 day and 50% of 9 day root leachates of *C. occidentalis* after 24 h, i.e. 1.00 on the rating scale (Table 4).

Total chlorophyll content was maximum in the control group, i.e. 23.04, but at 100% concentrations of shoot leachates of *C. occidentalis* it showed a significant reduction ($P < 0.05$) (10.95), which was found to be maximum in inhibition. Minimum inhibition was observed by root leachates of *C. occidentalis* at 50% concentrations (22.60) and it was found to be non-significant ($P > 0.05$). The total nitrogen and protein content of *Parthenium* was 5.70% and 35.62, respectively, in the control group but it was reduced to 0.90% and 5.62, respectively, at 100% concentrations of root leachates of *C. occidentalis* followed by 50% concentrations, in which 2.70% and 16.87 N (%) and protein content was observed, respectively, which was found to be significant at a 5% level (Table 5).

Discussion

Weeds such as *Achyranthes aspera* L., *Datura stramonium* L., *Calotropis procera* Ait., and *Cassia occidentalis* were commonly found in the close vicinity of *Parthenium*. Out of all these weeds at different sites, *C. occidentalis* was dominant, cohabiting with *Parthenium* successfully (Knox et al., 2006). A phytosociological survey of Islamabad and Rawalpindi revealed that *Cassia occidentalis* is replacing this weed gradually in patches (Shabbir & Bajwa, 2004). Oudhia (1999) conducted a phytosociological survey in the wastelands of Raipur district during the rainy season. He recorded about 27 weed species associated with *P. hysterophorus*. Among all weeds, *P. hysterophorus* and *Cassia tora* L. showed a high degree of sociability and formed into large colonies under arable soil habitats. Phytosociological structural composition was also assessed at Nemrut mountain (Tel et al., 2010). Joshi and Mahadevappa (1986) reported that *Cassia uniflora* Mill had successfully displaced this weed in Dharwad and surrounding areas under natural conditions. Joshi (1991a, 1991b) reported that 5 years after the introduction of *C. uniflora* to a site that was heavily infested with *Parthenium* weed, there

Table 3. Herbicidal potential of shoot and root leachates of *Cassia occidentalis* on bioactivity of *Parthenium hysterophorus*.

Exposure time (h)	Incubation periods and concentration ± Phytotoxic damage rating					
	3 day extracts		6 day extracts		9 day extracts	
	50%	100%	50%	100%	50%	100%
24 h (Shoot)	0.3 ± 0.4	0.3 ± 0.4	0.3 ± 0.4	0.3 ± 0.4	0.6 ± 0.4	1 ± 0.0
(Root)	0.0 ± 0.0	0.6 ± 0.4	0.6 ± 0.4	0.6 ± 0.4	0.3 ± 0.4	0.6 ± 0.4
48 h (Shoot)	1 ± 0.0	1 ± 0.0	2 ± 0.0	2 ± 0.0	2 ± 0.0	2 ± 0.0
(Root)	0.0 ± 0.0	1 ± 0.0	1 ± 0.0	1 ± 0.0	0.6 ± 0.4	0.6 ± 0.4
72 h (Shoot)	1.6 ± 0.4	2 ± 0.0	2 ± 0.0	2 ± 0.0	2 ± 0.0	3 ± 0.0
(Root)	1.3 ± 0.4	2 ± 0.0	2 ± 0.0	2 ± 0.0	2.3 ± 0.4	2.3 ± 0.4

n = 10; Mean ± Standard Error; Shoot cut bioassay; 0 = No phytotoxicity, 5 = Highest phytotoxicity

Table 4. Herbicidal potential of shoot and root leachates of *Cassia occidentalis* on bioactivity of *Parthenium hysterophorus*.

Exposure time (h)	**Incubation periods and concentration + Phytotoxic damage rating**					
	3 day extracts		**6 day extracts**		**9 day extracts**	
	50%	**100%**	**50%**	**100%**	**50%**	**100%**
24 h (Shoot)	2 ± 0.0	3 ± 0.0	2 ± 0.0	3 ± 0.0	3 ± 0.0	3 ± 0.0
(Root)	1 ± 0.0	1 ± 0.0	1 ± 0.0	1 ± 0.0	1 ± 0.0	2.6 ± 0.4
48 h (Shoot)	3 ± 0.0	3.3 ± 0.4	3 ± 0.0	3 ± 0.0	3 ± 0.0	4 ± 0.0
(Root)	1.6 ± 0.4	2 ± 0.0	2 ± 0.0	2 ± 0.0	2 ± 0.0	3 ± 0.0
72 h (Shoot)	3 ± 0.0	3 ± 0.4	3 ± 0.4	4 ± 0.0	4 ± 0.0	4 ± 0.0
(Root)	2 ± 0.0	2 ± 0.0	2 ± 0.0	2 ± 0.0	3 ± 0.0	4 ± 0.0

n = 10; Mean ± Standard Error; Seedling bioassay; 0 = No phytotoxicity, 4 = Highest phytotoxicity

Table 5. Effect of *Cassia occidentalis* on chlorophyll, nitrogen and protein content of *Parthenium hysterophorus*.

	Concentration	**Chl 'a'**	**Chl 'b'**	**Total Chl**	**N (%)**	**Protein**
Control		20.22 (4.49)	2.82 (1.67)	23.04 (4.80)	5.70 (2.38)	35.62 (5.96)
Shoot	50%	12.26* (3.50)	3.79 (1.94)	16.05* (4.00)	4.80 (2.19)	30 (5.97)
	100%	8.37* (2.89)	2.68 (1.63)	10.95* (3.30)	3.30* (1.81)	20.62* (4.54)
Root	50%	19.87 (4.45)	2.73 (1.65)	22.60 (4.75)	2.70* (1.64)	16.87* (4.10)
	100%	16.27 (4.03)	3.52 (1.87)	19.79 (4.44)	0.9* (0.94)	5.62* (2.37)

n = 10; Values within parentheses are square root transformed values; *Significant at 5% level

was an 84% reduction in the population of mature *Parthenium* weed plants. Mamatha and Mahadevappa (1988, 1992), based on their preliminary surveys, have reported that *Cassia sericea* Sw., *C. tora* L., *Tephrosia purpurea* L., and *Croton bonplandianum* Baill. restricted *Parthenium* invasion in many states in India.

According to Kumar and Soodan (2006) *Parthenium* infested areas under natural vegetation cover have a Shannon-Weaver index value of 2.544 and the weed has an insignificant presence with an IVI of 0.83%, as compared to *Parthenium* infested areas that do not contain natural vegetation cover, which have a S-W index value of 0.18 with an IVI of 79.10%.

Anjum et al. (2005) concluded that aqueous extracts of *Imperata cylindrica* L. exhibit the potential to control the germination and seedling growth of *Parthenium hysterophorus*. Root and shoot aqueous extracts of all applied concentrations significantly suppressed germination. The early seedling growth of *P. hysterophorus* was generally reduced significantly by extracts of 10% *Imperata cylindrica* and at higher concentrations. Increasing the concentration of the extract increased the inhibitory potential. Shoot extract was found to be a more effective inhibitor than root extract.

The herbicidal potential of the leaf leachates of plants like *Cymbopogon citratus*, *Withania somnifera* L., and *Calotropis procera* Ait. was assessed on *Parthenium*. The treatment of *Parthenium* shoots with leaf leachates of *Cymbopogon citratus* was much pronounced. The phytotoxic damage rating was found to be 3.66 in 9 day leaf leachate of 100% concentrations of *Cymbopogon citratus* followed by 3.00 and 2.00 in *Withania somnifera* and *Calotropis procera,* respectively (Knox & Paul, 2007). The plant leachates of *Cassia uniflora* have "Kolines" (a compound of plant origin affecting the germination and growth of other plant species) that accumulate in the soil consequent to the death of the plant and interfere with the germination and growth of *Parthenium* only.

Leachates from a number of other plants have also been tested for their allelopathic effects on *Parthenium hysterophorus*, including *Eucalyptus* spp. (Kohli et al., 1988; Theagrajan et al., 1995), neem, mulberry, and a wide range of woody plants of the Leguminosae (*Acacia* spp., *Albizia lebbek* L., *Cassia* spp., *Prosopis* spp.) (Dhawan, 1994, 1995; Dhawan & Dhawan 1995b, 1995c; Dhawan et al., 1996). Most tested positive, showing a significant inhibition of the *Parthenium* weed at different growth stages, and have been considered as possible biological control agents. More recent work with marigold (*Tagetes erectus*) at the National Research Centre for Weed Science Jabalpur (Madhya Pradesh), has shown that in field trials this plant can readily outcompete *P. hysterophorus* in a mixed stand, probably through allelopathy.

Thapar and Singh (2003) evaluated the allelopathic potential of the leaf leachates of *Amaranthus viridis* against *Parthenium hysterophorus*. A leaf leachate of *Amaranthus viridis* L. obtained after 9 days was responsible for the maximum inhibition of the biological activities of *Parthenium.* The chlorophyll and protein content of leaves in shoot-cut bioassay showed significant reductions at higher concentrations of leaf leachates. Treatment of the seeds with leaf leachates showed a marked effect on germination. A 49.41% reduction in seed germination was observed in 9 day leaf leachate at 100% concentrations of *A. viridis*. Swain et al. (2004) evaluated the allelopathic influence of *A. spinosus* on this weed following standard bioassay and biochemical techniques involving the germination and growth of seedlings and mature plants. They concluded that aqueous leachates obtained from the leaf, stem, and root showed strong inhibitory effects on the growth and multiplication of *P. hysterophorus.* Leaf leachates were found to be the most toxic in high concentrations (20% w/v), reducing germination by 95%, total chlorophyll content by 82.4%, and protein content by 65.5%. The post-emergence application of leaf leachates severely affected the growth of *Parthenium,* with wilting and seedling chlorosis noticed within 24 h of application.

Conclusion

It is amply indicative from the observations recorded that *Cassia occidentalis* does have some role to play by way of biomolecular interaction in suppressing and subsequently replacing *Parthenium hysterophorus,* an obnoxious weed of today. Thus, it provides an efficient and environment-friendly alternative to other time-consuming, costly, toxic, physical, and chemical methods.

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