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ALLELOPATHIC EFFECTS OF LEAVES EXTRACT OF *PARTHENIUM HYSTEROPHORUS* L. ON SEED GERMINATION OF THREE RICE VARIETIES

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Abstract

This study investigates the allelopathic effects of *Parthenium hysterophorus* L. leaf extracts on the germination and growth of three rice varieties (Hira dhan, BRRI dhan-28, and BRRI dhan-29) in Bangladesh. Leaf extracts of *P. hysterophorus* were prepared at different concentrations and applied to rice seeds in a controlled environment. Results showed that low concentrations of the extracts inhibited seed germination and growth, with significant differences among rice varieties ($p < 0.05$). Hira dhan exhibited the most sensitivity, with germination rates as low as 42.86% under high extract concentrations. In contrast, BRRI dhan-29 showed a stimulatory effect, particularly at low concentrations. The shoot and root lengths of Hira dhan and BRRI dhan-29 were significantly inhibited at higher concentrations, while BRRI dhan-28 demonstrated growth stimulation. The fresh and dry weights of roots and shoots varied significantly among the varieties with the greatest inhibitory effect observed in BRRI dhan-29. These findings align with previous studies, suggesting that allelochemicals in *P. hysterophorus*, such as parthenin and phenolic acids, play a critical role in inhibiting rice growth. The study emphasizes the need for further research on allelopathic interactions and suggests that controlling *P. hysterophorus* at the crop emergence stage could mitigate its suppressive effects on rice growth.

Introduction

Allelopathy is a phenomenon where plants, including microbes, release chemicals (allelochemicals) into the environment, which can have direct or indirect, positive or negative effects on other plants. Ecologically, allelopathic plants are important because they disrupt and reshape the natural biodiversity of surrounding plant life, influencing the composition and dynamics of plant communities (Bibi *et al.* 2023). All plant components, including leaves, roots, rhizomes, stems, flowers, pollens, fruits, and seeds, contain allelochemicals (Hussain and Reigosa 2021). Through the processes of evaporation, leaching, root exudation, and the breakdown of plant wastes in soil, allelochemicals are released into the environment (Fujii *et al.* 2022). Allelochemicals can inhibit the germination of seeds and prevent parasites from attaching themselves to host plants (Singh *et al.* 2003). *Parthenium hysterophorus* L. native to the New World, but it has been inadvertently brought to several nations, including Australia, Asia, Africa, and the Pacific Islands, where it has become a severe weed in rangelands and agriculture. It has been identified as a significant weed in field crops in over 45 countries which can germinate, grow, and flower in a variety of temperatures and photoperiods (Bajwa *et al.* 2016). It is an annual perennial plant with an erect and much-branched growth habit This upright, transient plant has a deep tap root system and can reach heights of 1.5–2 m. The leaves are pubescent and strongly dissected into narrow lobes. The small white flowers have five (rarely six, seven or eight) distinct

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ray florets and grow on the stem tips (Adkins and Shabbir 2014). It is an aggressive colonist of disturbed soil. As long as there is moisture present and a high germination rate, seeds can sprout year-round. A season may yield four or more subsequent cohorts of seedlings (Pandey and Dubey 1989). Additionally, the species generates chemical compounds that, when dispersed into the soil, cause other species to experience allelopathic effects (Rubaba *et al.* 2017). *P. hysterophorus* is a recently introduced, highly invasive weed in Bangladesh, and is now widespread in rice fields, particularly in the Mymensingh and Rajshahi divisions (Biswas *et al.* 2010). In the Haor regions of Bangladesh, the boro rice crop holds significant importance, with BRRI dhan-28 and BRRI dhan-29 being the predominant varieties, making up more than 90% of the cultivation in these areas. In the Chalan Beel area, Hira dhan is the main variety cultivated. Though Khatun *et al.* (2023) discovered allelopathic effects on diverse crops in the southwest parts of Bangladesh, the allelopathic effect on most consumed rice varieties was not done.

Hence the present study was aimed to investigate the intensity of the different concentrations of leaf and root extracts of *P. hysterophorus* on different varieties of rice and to evaluate the allelopathic effects of *P. hysterophorus* on seed germination, root, and seedling growth of three varieties of rice.

Materials and methods

The plants (*Parthenium hysterophorus* L. and *Oryza sativa* L.) used in the present study were collected from the Chalan Beel region and Gazipur districts. After collecting and giving them a thorough water wash, fresh *P. hysterophorus* plants were allowed to dry in the shade for 10 days. Samples of leaves were separated, ground into powder, and kept in plastic containers at room temperature (around 25°C). For preparing stock solution of 100% concentration, 100 g of powdered leaves were soaked in 100 ml of distilled water for 24 hrs at room temperature. A series of solutions with varying dilution strengths were prepared using the extracts as the stock solution (Thakur and Kunjam 2020). For the low concentrations of aqueous extracts of *P. hysterophorus*, T_0, T_1, T_2, T_3, T_4 and T_5 corresponded to concentrations of 0, 2, 4, 6, 8 and 10%, respectively. Meanwhile, for the high concentrations, T_0, T_1, T_2 and T_3 corresponded to 0, 6, 30 and 50%, respectively. To surface sterilize each of the seven healthy seeds was soaked in 2% sodium hypochlorite for 15 min. Six Petri plates were sterilized in an autoclave for one hr at 121°C after being cleaned, dried, and ready for testing. The seeds were then placed for germination in sterile Petri dishes using two layers of Whatman No. 1 filter paper, moistened with 10 ml of various aqueous extract concentrations. Seven seeds were used in each treatment setup. Distilled water was used to set up an additional set of controls. The Petri dishes were kept in a greenhouse for ten days, with an average temperature of 30°C and humidity of 67%. After ten days the germination rate, root and shoot length (Fig. 1), no of roots, fresh and dry weight of roots and shoots were measured. Statistical analysis was done using MS Excel and Minitab 19.

Results and Discussion

The seed germination response of three rice varieties under low concentrations of *P. hysterophorus* leaf extract is presented in Table 1. Germination rates ranged from 42.86 to 100%, with Hira dhan showing increasing inhibition as concentrations rose, peaking at a 42.86% germination rate at the T_3 treatment. BRRI-28 experienced a 14.29% reduction at T_1 and T_3, while BRRI-29 exhibited a 40% increase across all concentrations compared to the control (Table 1). Shoot length data showed that increasing concentrations of leaf extract significantly suppressed the growth of Hira dhan and BRRI-29, with the strongest inhibition at T_2 and T_5. BRRI-28, however, showed stimulation at T_5 with a shoot length of 7.471 cm, while BRRI-29's lowest length was 5.271 cm at T_5 (Table 1). Statistical analysis revealed significant differences in shoot length among the varieties ($p < 0.05$) (Table 5). In terms of root length, T_1 and T_5 treatments exhibited mild stimulation across all varieties. The strongest inhibitory effect was on BRRI-29 at T_3 (4.157 cm), while Hira dhan experienced minimal inhibition at T_1 (7.542 cm). The maximum stimulation was observed for Hira dhan at T_5 (7.8 cm), compared to the control of 7.314 cm (Table 1). The fresh shoot weight declined progressively with higher concentrations, with BRRI-29 showing the greatest reduction at T_2 (3.857 mg), and Hira dhan experiencing the least inhibition at T_3 (22.667 mg). A significant reduction in dry shoot weight was also observed, particularly for BRRI-29 at T_5 (1.729 mg) (Table 2). Root number followed a similar pattern, with Hira dhan showing the highest inhibition at T_4 (3 roots), while BRRI-29 had a stimulating effect at T_4 (5.857 roots) (Table 1). Fresh and dry root weights decreased most notably for BRRI-29 at T_3, while Hira dhan showed resilience at T_2 and T_5, with significant variety and concentration effects ($p < 0.001$). (Tables 2 and 5).

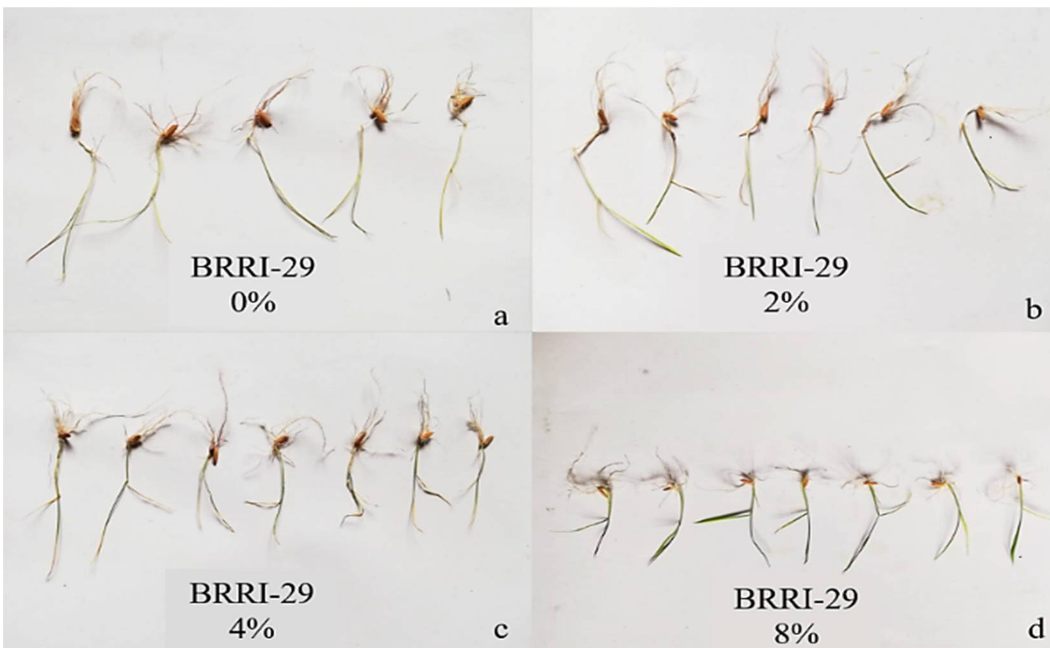

Fig. 1. Measurement of root and shoot length of BRRI-29 in different concentration treatments (0% control, 2%, 4%, and 8%).

Results from Table 3 indicate that Hira dhan experienced inhibition at high concentrations of *P. hysterophorus* leaf extract across all doses except for T_2, which exhibited slight stimulation. The most significant inhibitory effect for Hira dhan occurred at T_1, with a 42.86% germination rate (a 49.94% reduction). Germination rates ranged from 42.86 to 100%. BRRI-28 displayed similar inhibition, while BRRI-29 saw a stimulatory effect, with the highest being a 28.57% increase in germination (Table 3). Regarding shoot length, high concentrations inhibited both Hira dhan and BRRI-29, with the most significant inhibition recorded for BRRI-29 at T_3 (5.143 cm). Conversely, Hira dhan showed the least inhibition at T_3 (7.783 cm), and BRRI-28 exhibited

Table 1. Germination percentage, shoot and root length, and number of roots of three rice varieties at different low concentrations of aqueous leaf extracts of *Parthenium hysterophorus*.

	Germination percentage (%)			Shoot length (cm)			Root length (cm)			Number of roots		
Treatment	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29	Hira dhan (mg)	BRRI-28 (mg)	BRRI-29 (mg)
T_0	85.71	100	71.43	9 ± 1.527	6.071 ± 1.035	6.36 ± 0.416	7.314 ± 0.942	3.8 ± 0.730	4.4 ± 0.430	26.00 ± 14.306	20.857 ± 2.673	13.167 ± 3.817
T_1	57.14	85.71	85.71	7.885 ± 1.326	7.257 ± 0.948	7.433 ± 1.426	7.542 ± 0.989	6.786 ± 0.790	4.85 ± 0.497	15.286 ± 12.079	11.857 ± 5.367	6.00 ± 0.707
T_2	85.71	100	100	6.66 ± 1.252	6.917 ± 0.371	5.471 ± 1.026	6.76 ± 1.009	5.4 ± 0.405	4.657 ± 0.802	8.00 ± 1.581	20.5 ± 2.258	3.857 ± 1.574
T_3	42.86	85.71	100	7.367 ± 1.929	6.65 ± 0.748	5.442 ± 0.714	5.833 ± 2.309	5.7 ± 0.395	4.157 ± 0.190	22.667 ± 9.452	6.333 ± 1.633	5.143 ± 3.132
T_4	57.14	100	100	7.767 ± 2.289	6.114 ± 1.190	6.229 ± 0.898	6.3 ± 2.307	6.086± 1.001	4.971 ± 0.879	21.667 ± 10.408	6.714 ± 1.604	5.00 ± 2.309
T_5	71.43	100	100	6.6 ± 0.993	7.471 ± 1.174	5.271 ± 0.577	7.8 ± 0.906	4.9 ± 0.735	4.443 ± 0.483	11.25 ± 1.893	9.429 ± 2.760	4.429 ± 1.988

T_0 = Control, T_1 = 2% conc. (aq.), $T_{2\,=}$ 4% conc. (aq.), $T_{3\,=}$ 6% conc. (aq.), $T_{4\,=}$ 8% conc. (aq.), T_5 = 10% conc. (aq.) (aq. = aqueous) ("-" indicates reduction and "+" indicates stimulation).

Table 2. Fresh and dry weight of shoots and roots of three rice varieties at different low concentrations of aqueous leaf extracts of *Parthenium hysterophorus*.

Treatment	Fresh weight of shoots (mg)			Dry weight of shoots (mg)			Fresh weight of roots (mg)			Dry weight of roots (mg)		
	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29
T_0	26 ± 14.306	20.857 ± 2.673	13.167 ± 3.817	12.286 ± 6.993	3.714 ± 1.704	4.6 ± 1.140	8.429 ± 2.149	6.00 ± 2.449	4.4 ± 1.517	4.143 ± 2.116	3.143 ± 0.899	3.2 ± 1.095
T_1	15.286 ± 12.079	11.857 ± 5.367	6.00 ± 0.707	7.00 ± 5.132	5.00 ± 1.155	5.167 ± 1.169	9.714 ± 5.707	7.857 ± 1.676	4.833 ± 1.169	4.286 ± 2.563	3.571 ± 0.787	2.833 ± 0.408
T_2	8.00 ± 1.581	20.5 ± 2.258	3.857 ± 1.574	6.00 ± 1.00	4.667 ± 1.033	3.143 ± 1.069	8.00 ± 1.225	9.667 ± 2.338	4.857 ± 1.464	5.4 ± 1.673	4.333 ± 0.516	4.00 ± 1.00
T_3	22.667 ± 9.452	6.333 ± 1.633	5.143 ± 3.132	6.333 ± 6.11	5.833 ± 0.753	1.857 ± 1.464	5.667 ± 4.163	5.5 ± 1.378	3.571 ± 1.902	3.00 ± 2.00	5.00 ± 1.265	1.043 ± 0.950
T_4	21.667 ± 10.408	6.714 ± 1.604	5.00 ± 2.309	8.00 ± 6.083	5.571 ± 1.718	3.714 ± 1.604	6.333 ± 4.041	6.714 ± 1.496	4.286 ± 1.380	2.667 ± 1.528	5.571 ± 1.272	3.429 ± 1.134
T_5	11.25 ± 1.893	9.429 ± 2.760	4.429 ± 1.988	5.00 ± 0.817	5.286 ± 1.380	1.729 ± 1.087	5.5 ± 2.887	6.00 ± 1.633	4.00 ± 2.160	3.75 ± 2.062	4.286 ± 1.496	1.186 ± 1.016

T_0 = Control, T_1 = 2% conc. (aq.), T_2 = 4% conc. (aq.), T_3 = 6% conc. (aq.), T_4 = 8% conc. (aq.), T_5 = 10% conc. (aq.) (aq. = aqueous) ("-" indicates reduction and "+" indicates stimulation).

Table 3. Germination percentage, shoot and root length, and number of roots of three rice varieties at different high concentrations (2-10%) of aqueous leaf extracts of *Parthenium hysterophorus*.

	Germination percentage (%)			Shoot length (cm)			Root length (cm)			Number of roots		
Treatment	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29
T_0	85.71	100.0	71.43	9.00 ± 1.527	6.071 ± 1.035	6.36 ± 0.416	7.314 ± 0.942	3.8 ± 0.730	4.4 ± 0.430	4.714± 2.214	5.857 ± 0.899	6.2 ± 1.304
T_1	42.86	100.0	100	7.80 ± 0.889	7.986 ± 0.790	6.371 ± 0.734	11.233 ± 1.484	6.029 ± 1.473	5.143 ± 0.887	8.00 ± 1.00	5.714 ± 0.756	6.571 ± 0.976
T_2	100	100.0	85.71	6.329 ± 1.847	7.386 ± 1.544	5.74 ± 3.143	5.871 ± 1.083	6.386 ± 0.914	5.44 ± 1.242	7.286± 2.870	6.857 ± 1.773	6.00 ± 1.581
T_3	85.71	100.0	100.0	7.783 ± 1.457	7.686 ± 1.262	5.143 ± 1.601	5.133 ± 1.714	6.086 ± 0.652	5.571 ± 1.811	7.667± 2.251	6.143 ± 0.690	6.143 ± 1.773

T_0 = Control, T_1 = 6% conc. (aq.), T_2 = 30% conc. (aq.), T_3 = 50% conc. (aq.) (aq. = aqueous).

Table 4. Fresh and dry weight of shoots and roots of three rice varieties at different high concentrations of aqueous leaf extracts of *Parthenium hysterophorus*.

	Fresh weight of shoots (mg)			Dry weight of shoots (mg)			Fresh weight of roots (mg)			Dry weight of roots (mg)		
Treatment	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29	Hira dhan	BRRI-28	BRRI-29	Hira dhan (mg)	BRRI-28 (mg)	BRRI-29 (mg)
T_0	26.0 ± 14.306	20.857 ± 2.673	13.167 ± 3.817	12.286 ± 6.993	3.714 ± 1.704	4.60 ± 1.140	8.429 ± 2.149	6.00 ± 2.449	4.40 ± 1.517	4.143 ± 2.116	3.143 ± 0.899	3.20 ± 1.095
T_1	32.75 ± 0.354	19.667 ± 4.757	18.117 ± 2.326	1.75 ± 2.713	4.967 ± 1.154	4.167 ± 0.878	21.5 ± 0.141	7.617 ± 2.640	13.15 ± 7.825	5.183 ± 0.722	4.133 ± 0.995	5.45 ± 0.644
T_2	32.633 ± 5.959	24.6 ± 7.368	22.05 ± 12.247	6.367 ± 0.745	4.483 ± 1.389	3.85 ± 2.009	17.417± 9.579	18.283 ± 9.833	6.55 ± 1.865	5.067 ± 1.219	2.867 ± 0.680	3.00 ± 1.503
T_3	42.6 ± 6.135	19.783 ± 2.728	15.8 ± 3.002	5.583 ± 2.896	4.767 ± 0.413	3.08 ± 0.192	27.56 ± 16.666	13.1 ± 6.045	11.94 ± 3.190	5.233 ± 1.686	4.317 ± 0.567	5.35 ± 1.585

T_0 = Control, T_1 = 6% conc. (aq.), T_2 = 30% conc. (aq.), T_3 = 50% conc. (aq.) (aq. = aqueous).

stimulatory effects, with the combined effect of concentrations and varieties being highly significant ($p < 0.001$) (Tables 3 and 6). Root length analysis revealed a notable reduction in Hira dhan across all treatments except T_1. The highest inhibition occurred at T_3 (5.133 cm). BRRI-28 and BRRI-29 exhibited stimulatory effects under high concentrations of the extract. The maximum stimulation was observed in Hira dhan at T_1 (11.233 cm), while the combined effects of concentration and variety showed significant results ($p < 0.05$) (Table 3 and 6). For the fresh weight of shoots, Hira dhan and BRRI-29 demonstrated a stimulatory effect across all treatments, while BRRI-28 showed inhibition at T_1 and T_3. The highest stimulation was recorded for Hira dhan at T_3 (42.6 mg) (Table 4). Similar patterns were observed in the dry weight of shoots, with significant variation ($p < 0.001$) in all three varieties (Table 6). The number of roots exhibited variability, with Hira dhan showing stimulation across all treatments. No significant difference was observed for the combined effects of concentrations and varieties. Additionally, all varieties displayed stimulation in the fresh and dry weights of roots, with Hira dhan reaching the highest fresh weight at T_3 (27.56 mg) (Table 4). Significant differences were observed in root weights ($p < 0.001$) (Table 6).

Table 5. Analysis of variance (ANOVA) of different parameters of root and shoot at low concentrations of leaf extracts of *Parthenium hysterophorus*.

Parameters	Source of variation	F-value	p-value
Root length vs Variety and Concentration	Var.	2.19	0.117^{ns}
	Con.	2.78	0.021*
	Var. × Con.	3.70	0.000***
Shoot length vs Variety and Concentration	Var.	2.45	0.091^{ns}
	Con.	2.94	0.016*
	Var. × Con.	2.92	0.003**
No. of roots vs Variety and Concentration	Var.	15.11	0.000***
	Con.	1.62	0.160^{ns}
	Var. × Con.	2.20	0.023*
Fresh weight of roots vs Variety and Concentration	Var.	8.03	0.001***
	Con.	4.48	0.001***
	Var. × Con.	2.49	0.010**
Fresh weight of shoots vs Variety and Concentration	Var.	10.86	0.000***
	Con.	6.52	0.000***
	Var. × Con.	3.67	0.000***
Dry weight of roots vs Variety and Concentration	Var.	9.29	0.000***
	Con.	2.18	0.062^{ns}
	Var. × Con.	3.78	0.000***
Dry weight of shoots vs Variety and Concentration	Var.	8.23	0.000***
	Con.	3.74	0.004**
	Var. × Con.	3.51	0.000***

***$p<0.001$, ** $p<0.01$, $p<0.05$ and ns = non-significant.

Table 6. Analysis of variance (ANOVA) of different parameters of root and shoot at high concentrations of leaf extracts of *Parthenium hysterophorus*.

Parameters	Source of variation	F-value	p-value
Root length vs Variety and Concentration	Var.	2.26	0.112^{ns}
	Con.	0.35	0.791^{ns}
	Var. × Con.	2.61	0.024*
Shoot length vs Variety and Concentration	Var.	6.38	0.003**
	Con.	0.45	0.715^{ns}
	Var. × Con.	4.22	0.001***
No. of roots vs Variety and Concentration	Var.	0.80	0.455^{ns}
	Con.	1.41	0.248^{ns}
	Var. × Con.	1.97	0.081^{ns}
Fresh weight of roots vs Variety and Concentration	Var.	2.88	0.063^{ns}
	Con.	4.48	0.006**
	Var. × Con.	1.81	0.112^{ns}
Fresh weight of shoots vs Variety and Concentration	Var.	10.66	0.000***
	Con.	4.04	0.011*
	Var. × Con.	2.54	0.029*
Dry weight of roots vs Variety and Concentration	Var.	0.75	0.477^{ns}
	Con.	3.71	0.016*
	Var. × Con.	5.28	0.000***
Dry weight of shoots vs Variety and Concentration	Var.	9.58	0.000***
	Con.	3.34	0.025*
	Var. × Con.	6.24	0.000***

***$p<0.001$, ** $p<0.01$, $p<0.05$ and ns = non-significant.

Hassan *et al.* (2018) reported that *Parthenium* extracts at a concentration of 25 g L^{-1} had a mild stimulatory effect on seed germination, while higher concentrations led to an inhibitory response. This aligns closely with our findings, as we observed that seed germination in Hira dhan was similarly affected by a 30% leaf extract concentration. The highest seed germination in Jowar occurred with 25% leaf extract of *Parthenium*, while the lowest germination was observed at 75% concentration. Additionally, *Parthenium* leaf extract at 25 and 50% concentrations had a stimulating effect on Jowar seeds, which is consistent with the present results in BRRI-29, where similar concentrations also produced a stimulatory effect. Various *P. hysterophorus* concentrations had a substantial impact on the shoot and root weight of various crops and weeds (Hassan *et al.* 2018). Rashid *et al.* (2008) reported that increased *Parthenium* root extract concentration reduced maize and sorghum root length, which contrasts with our present study. In our research, the root length of Hira Dhan, BRRI-28 and BRRI-29 was not reduced with increasing concentrations of *Parthenium* leaf extract. Imad *et al.* (2021) investigated the allelopathic effects of *Parthenium hysterophorus* aqueous extract on the seed germination and seedling growth of eight selected plant species: *Allium sativum* L. (Garlic), *Brassica campestris* L. (Mustard), *Coriandrum sativum* L. (Coriander), *Cucumis sativus* L. (Cucumber), *Eruca sativa* Mill. (Taramira), *Solanum* *lycopersicum* L. (Tomato), *Trifolium pratense* L. (Clover), and *Triticum aestivum* L. (Wheat). They found that increasing concentrations of *Parthenium* extracts led to a reduction in germination rates, which differed with our findings, as no such trend was observed in our study.

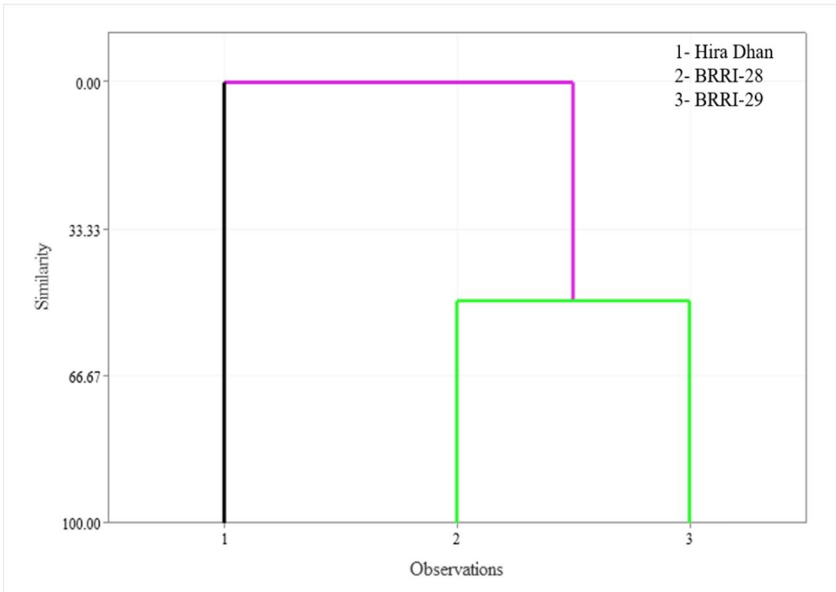

Fig. 2. Dendrogram showing the sensitivity of plants against leaf extracts of *Parthenium hysterophorus*.

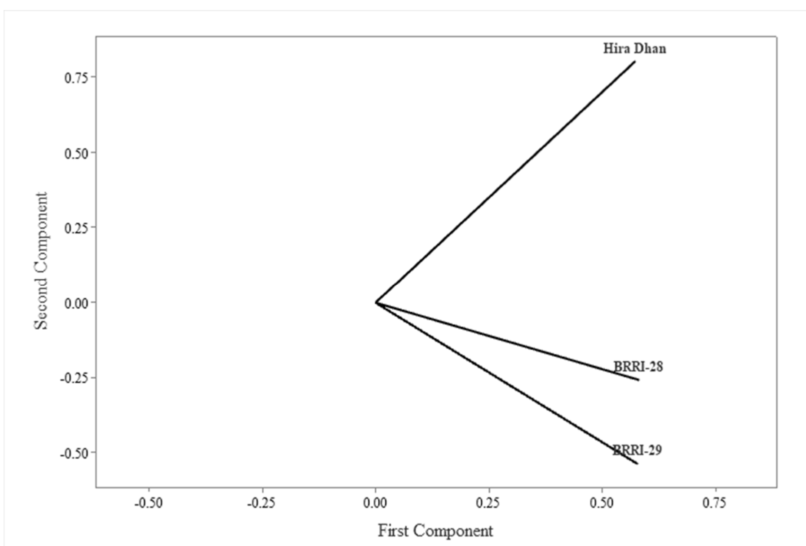

Fig. 3. Principal component analysis (PCA) and graphical correlation among the indicator plants treated with *Parthenium hysterophorus* leaf extracts.

Thakur and Kunjam (2020) investigated the allelopathic effects of leaf extract and found that increasing concentrations led to a reduction in biomass of the test crop plants. Specifically, a 10% extract concentration was shown to inhibit the dry weight of soybean and wheat seedlings. These findings are consistent with our study, which observed similar inhibitory effects on the dry weight of shoots in Hira Dhan and BRRI-29 at a 10% extract concentration.

Allelochemicals can impact a variety of processes, including reducing material uptake, suppressing the activity of growth hormones like IAA and Gibberellins (Kefeli and Turetskayan 1976), interfering with photosynthesis, and causing a decrease in root cell mitotic activity (Bukolova 1971), which can lead to a decline in length of shoot, root, and seed germination. Verma *et al.* (2020) found that the main plant growth inhibitors include parthenin and other phenolic acids such as para hydroxybenzoic acid, caffeic acid, vanillic acid, anisic acid, and chlorogenic acid. Cluster analysis grouped rice varieties into two main classes based on their response to *P. hysterophorus* extracts: BRRI-28 and BRRI-29 in one group, and Hira dhan, which showed greater sensitivity, in another (Fig. 2). Principal component analysis (PCA) confirmed these findings, showing distinct responses of BRRI-28 and BRRI-29 with Hira dhan (Fig. 3).

The findings of the present study demonstrated that *Parthenium* leaf extract affected the native rice variety (Hira dhan) comparatively more than those of the hybrid rice varieties (BRRI-28 and BRRI-29). The effects were almost the same for BRRI-28 and BRRI-29. The outcomes of the experiments for the leaf and root extracts of *Parthenium* were essentially the same. It was occasionally found that leaf or root extract encouraged growth at very high concentrations while inhibiting it at low concentrations. Overall, it was observed that the high concentration leaf extracts did not significantly alter roots. Furthermore, there was a noticeable decrease in the growth of rice seedlings at low or high concentration leaf extracts and different concentrations of root extract. Consequently, more research on the interaction between allelochemicals and crop species is necessary to interpret the mechanism of such allelopathic effects. It is essential to keep this weed under control during the emergence stage at agro crop fields to avoid its allelopathic based crop growth suppression. Further research on this field is necessary and should be conducted.

References

Adkins S and Shabbir A 2014. Biology, ecology and management of the invasive parthenium weed (*Parthenium hysterophorus* L.). Pest Manag. Sci. **70**(7):1023-29.

Bajwa AA, Chauhan BS, Farooq M, Shabbir A and Adkins SW 2016. What do we really know about alien plant invasion? A review of the invasion mechanism of one of the world's worst weeds. Planta **244**: 39-57.

Bibi S, Bibi A, Al-Ghouti MA and Abu-Dieyeh MH 2023. Allelopathic Effects of the Invasive *Prosopis juliflora* (Sw.) DC. on Native Plants: Perspectives toward Agrosystems. Agronomy **13**(2): 590.

Biswas O, Paul KP, Ghosh S and Karim SR 2010. Allelopathic effects of parthenium weed debris in soil on the emergence and development of rice. J. Agrofor. Environ. **4**:193-196.

Bukolova TP 1971. A study of the mechanism of action of water-soluble substances of weeds on cultivated plants. Physiol. Biochem. Basis Plant Interact Phytocen. **2**: 66-69.

Fujii Y, Pariasca D, Shibuya T, Yasuda T, Kahn B and Waller GR 2022. Plant-box method: a specific bioassay to evaluate allelopathy through root exudates. *In*: Allelopathy. CRC Press. pp. 39-56.

Hassan G, Rashid HU, Amin A, Khan IA and Shehzad N 2018. Allelopathic effect of *Parthenium hysterophorus* on germination and growth of some important crops and weeds of economic importance. Planta Daninha. **36**: e018176372.

Hussain MI and Reigosa MJ 2021. Secondary metabolites, ferulic acid and p-hydroxybenzoic acid induced toxic effects on photosynthetic process in *Rumex acetosa* L. Biomolecules **11**(2): 233.

Imad M, Idrees M, Hadi F, Memon NH and Zhang Z 2021. Allelopathic effect of *Parthenium hysterophorus* extract on seed germination and seedling growth of selected plants. Pak. J. Bot. **53**(6): 2187-97.

Kefeli VI and Turetskaya RK 1976. Comparative effect of natural growth inhibitors, narcotics and antibiotics on plant growth. Fiziol. Rast. Mosk. **14**: 796-803.

Khatun MS, Biswas PK, Mandal MSH, Yeasmin M, Akhi SS, Mehraj H and Masum SM 2023. Prevalence and allelopathic effect of *Parthenium hysterophorus* on crops in southwest regions of Bangladesh. Ecol. J. **5**(2): 155-161.

Pandey HN and Dubey SK 1989. Growth and population dynamics of an exotic weed *Parthenium hysterophorus* L. Proc. Indian Acad. Sci. Plant Sci. **99**(1): 51-58.

Rashid H, Khan MA, Amin A, Nawab K, Hussain N and Bhowmik PK 2008. Effect of *Parthenium hysterophorus* L., root extracts on seed germination and growth of maize and barley. Am. J. Plant Sci. Biotechnol. **2**(2): 51-55.

Rubaba O, Chimbari M and Mukaratirwa S 2017. Scope of research on *Parthenium hysterophorus* in Africa. S. Afr. J. Plant Soil. **34**(5): 323-32.

Singh HP, Batish DR and Kohli RK 2003. Allelopathic interactions and allelochemicals: new possibilities for sustainable weed management. CRC Crit. Rev. Plant Sci. **22**(3-4): 239-311.

Thakur GS and Kunjam S 2020. Allelopathic potential of *Parthenium hysterophorus* on wheat, *Triticum aestivum*. rice, *Oryza sativa*, soybean, *Glycine max* and pigeonpea, *Cajanus cajan*. Flora fauna. **26**(2): 197-205.

Verma AK, Maurya SK, Kumar A, Barik M, Yadav V, Umar B, Lawal M, Usman ZA, Adam MA and Balarabe BA 2020. Inhibition of multidrug resistance property of Candida albicans by natural compounds of *Parthenium hysterophorus* L. An In-Silico approach. J. Pharmacogn. Phytochem. **9**(3): 55-64.

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