

ALLELOPATHIC EFFECTS OF *PARTHENIUM HYSTEROPHORUS* L. ON EARLY CROP ESTABLISHMENT A CONCENTRATION-RESPONSE STUDY IN RICE, GREEN GRAM, AND MAIZE

Dr. Mamta J. Patange^{1*}, Dr. Tushar U. Patel², Dr. Shubhangi J. Dhage³, Dr. Sonal S. Tripathi⁴, Dr. P. K. Waghmare⁵, Dr. V. P. Suryavanshi⁶, Dr. Karuna M. Chaudhri⁷, Dr. Priya R. Chaudhari⁸

^{1*}Assistant Professor, Dept. of Agronomy, VNMKV, Parbhani, Maharashtra, India. Email: patangemj456@gmail.com

²Associate Professor, Dept. of Agronomy, NAU, Navsari, Gujarat, India.

³Assistant Professor, dept. of SSAC, Dr. PDKV, Akola, Maharashtra, India.

⁴Professor, Dept. of SSAC, NAU, Navsari, Gujarat, India.

⁵Assistant Professor, Dept. of Agronomy, VNMKV, Parbhani, Maharashtra, India.

⁶Professor, Dept. of Agronomy, VNMKV, Parbhani, Maharashtra, India.

⁷Assistant Professor, Dept. of Agronomy, JAU, Junagadh, Gujarat, India.

⁸Assistant Professor, Dept. of Agronomy, JAU, Junagadh, Gujarat, India.

ABSTRACT

Parthenium hysterophorus L. is an invasive weed with a chemically mediated competitive advantage that may suppress crop establishment through allelopathy. This study quantified the effects of aqueous *Parthenium* leaf extract on seed germination and early seedling growth of rice (*Oryza sativa* L.), green gram (*Vigna radiata* L.), and maize (*Zea mays* L.). Leaves collected before flowering were shade dried, extracted at 10 g 100 mL⁻¹ for 24 h, and diluted to 2, 4, 6, 8, and 10%; distilled water served as the control. Ten seeds per Petri dish were evaluated in a completely randomized design with four replicates. Germination, plumule and radicle length, dry matter, and vigour index were measured. The response was strongly concentration dependent. At the final observation, rice germination declined from 100% in the control to 46.5% at 6% extract and 0% at 8–10%; green gram declined to 47.5%, 20%, and 0% at 6, 8, and 10%, respectively; and maize declined to 60%, 35.5%, and 20% at the same concentrations. Radicles were more sensitive than plumules. At 6% extract, vigour index fell to 57.6 in rice, 213 in green gram, and 328 in maize, compared with untreated values of 1263.7, 2082, and 3160. At 10%, rice and green gram had no measurable seedling growth, while maize retained only 0.48 cm plumule and 0.03 cm radicle growth. The findings demonstrate that *Parthenium* leaf residues can impose severe establishment risk at concentrations likely to occur near decomposing biomass, and that germination alone underestimates injury because root elongation and vigour decline earlier. Crop-safe residue management should therefore prevent direct contact between fresh or incompletely decomposed *Parthenium* biomass and germinating seed.

KEYWORDS: allelopathy; crop establishment; germination; *Parthenium hysterophorus*; phytotoxicity; radicle sensitivity; vigour index

1. INTRODUCTION

Parthenium hysterophorus L. is an annual herb in the Asteraceae that has expanded from its native range in the American tropics to disturbed habitats, croplands, roadsides, wastelands, and pasture systems across several continents. Its ecological success arises from rapid emergence, prolific seed production, environmental plasticity, and the ability to maintain populations under variable moisture and temperature conditions [1–3]. These characteristics create recurrent competition with crops for water, mineral nutrients, light, and space and make prevention of seed-bank enrichment a central management goal.

In addition to resource competition, *Parthenium* exerts allelopathic interference. Allelopathy is the chemical influence of one plant on another through compounds released by living tissues, leachates, root exudates, pollen, and decomposing residues. *Parthenium* tissues contain sesquiterpene lactones such as parthenin and a range of phenolic compounds, including caffeic and p-coumaric acid derivatives, which can disrupt germination, cell division, elongation, membrane processes, enzyme activity, and nutrient acquisition [4–8]. The biological response is expected to be concentration dependent and may differ among crop species and organs.

Seed germination is a critical bottleneck in crop production. Even when a seed remains viable, delayed emergence, reduced radicle penetration, or reduced seedling vigour can compromise stand uniformity and subsequent competition with weeds. A rigorous allelopathy assessment should therefore include germination, root and shoot growth, dry matter, and a composite vigour index rather than relying on a single endpoint. The present study addressed this need by comparing three agronomically important crops representing two cereals and one pulse.

The objective was to examine the allelopathic effects of aqueous *Parthenium* leaf extract at 2–10% on germination and early seedling growth of rice, green gram, and maize under controlled laboratory conditions. The working hypothesis was that increasing extract concentration would reduce all response variables, with root growth showing greater sensitivity than shoot growth.

2. MATERIALS AND METHODS

2.1 Experimental design and plant material

The laboratory experiment was conducted at approximately 25°C using a completely randomized design with four replications. The test crops were rice hybrid GRH-2, green gram CO-4, and maize hybrid GAYMH-3. Each replicate consisted of a sterile 9-cm Petri dish containing ten surface-sterilized seeds on two layers of blotting paper. Distilled water was used for the untreated control.

Table 1. Laboratory assay structure

Treatment class	Concentration	Seeds/dish	Replicates	Assessment
Leaf extract	2%	10	4	Crop-specific final count; 7 DAS for rice and maize; 6 DAS for green gram
Leaf extract	4%	10	4	
Leaf extract	6%	10	4	
Leaf extract	8%	10	4	
Leaf extract	10%	10	4	
Control	Distilled water	10	4	

2.2 Preparation of aqueous extract

Parthenium leaves were collected before flowering, washed with tap water, and shade dried. Ten grams of air-dried leaves were ground and soaked in 100 mL distilled water for 24 h in darkness at room temperature. The suspension was filtered through two layers of muslin cloth and then through filter paper. The filtrate was adjusted to 100 mL and treated as the 10% stock solution. Dilutions of 2, 4, 6, and 8% were prepared from the stock and stored at 4°C until use.

2.3 Measurements and statistics

Petri dishes were moistened with 10 mL of the respective extract, covered, and maintained under laboratory conditions. Germinated seeds were counted at the final crop-specific observation. Five seedlings per dish were selected for plumule and radicle measurement. Seedlings were oven dried to constant mass and expressed as mg plant⁻¹. Vigour index was calculated as germination percentage × (plumule length + radicle length) [9]. The source thesis analyzed treatment effects by analysis of variance under a completely randomized design and reported standard error, critical difference at P=0.05, and coefficient of variation. This article reports source means and presents additional descriptive visualizations; no new inferential tests are claimed.

3. RESULTS

3.1 Germination response

The germination response declined monotonically with increasing extract concentration, although the magnitude differed among crops. Rice was highly sensitive at concentrations above 4%; final germination was 92.5% at 2%, 77.5% at 4%, 46.5% at 6%, and 0% at both 8 and 10%. Green gram showed 96.5% germination at 2%, 72.5% at 4%, 47.5% at 6%, 20% at 8%, and 0% at 10%. Maize was comparatively less inhibited at the germination endpoint, retaining 98% at 2%, 75% at 4%, 60% at 6%, 35.5% at 8%, and 20% at 10%. All controls reached 100% final germination.

Table 2. Germination response to increasing *Parthenium* leaf-extract concentration

Crop	Final germination at 2/4/6/8/10% (%)	Control (%)	Minimum observed (%)	Maximum loss vs control (%)
Rice	92.5/77.5/46.5/0.0/0.0	100.0	0.0	100.0
Green gram	96.5/72.5/47.5/20.0/0.0	100.0	0.0	100.0
Maize	98.0/75.0/60.0/35.5/20.0	100.0	20.0	80.0

3.2 Plumule, radicle, dry matter, and vigour

Growth responses were more severely affected than germination at low to intermediate concentrations. In rice, 2% extract reduced plumule and radicle length to 4.10 and 3.80 cm, respectively, from 6.87 and 5.77 cm in the control. At 6%, these values declined to 0.74 and 0.50 cm, and both were zero at 8–10%. In green gram, the radicle declined from 7.30 cm in the control to 1.56 cm at 2% and 0.18 cm at 6%, while the plumule remained 4.29 cm at 6%. Maize showed the same order of sensitivity: 2% extract caused only modest reduction, but at 6% the radicle was 0.69 cm compared with 15.20 cm in the control.

Table 3. Early seedling-growth response to *Parthenium* extract

Crop	Plumule at 2/6/10% (cm)	Radicle at 2/6/10% (cm)	Dry wt. at 2/6/10% (mg plant ⁻¹)	VI at 2/6/10%	Control plumule; radicle; VI
Rice	4.10/0.74/0.00	3.80/0.50/0.00	29.71/2.25/0.000	726/58/0	6.87; 5.77; 1264
Green gram	10.07/4.29/0.00	1.56/0.18/0.00	21.33/10.19/0.000	1122/213/0	13.52; 7.30; 2082
Maize	14.19/4.77/0.48	13.50/0.69/0.03	51.33/11.08/0.004	2713/328/10	16.40; 15.20; 3160

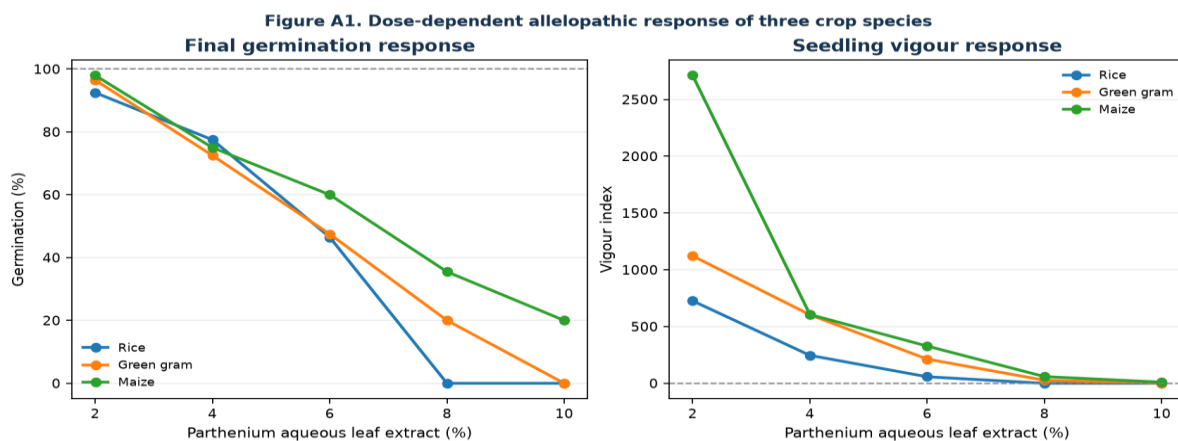


Figure A1. Source-mean dose-response curves for final germination and seedling vigour.

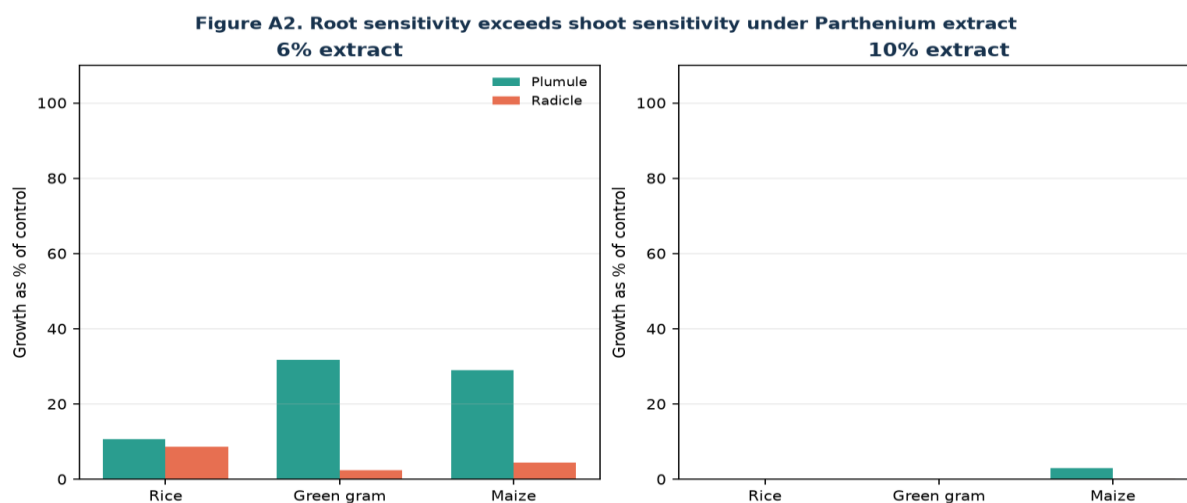


Figure A2. Plumule and radicle growth expressed as percentages of the untreated control at 6 and 10% extract.

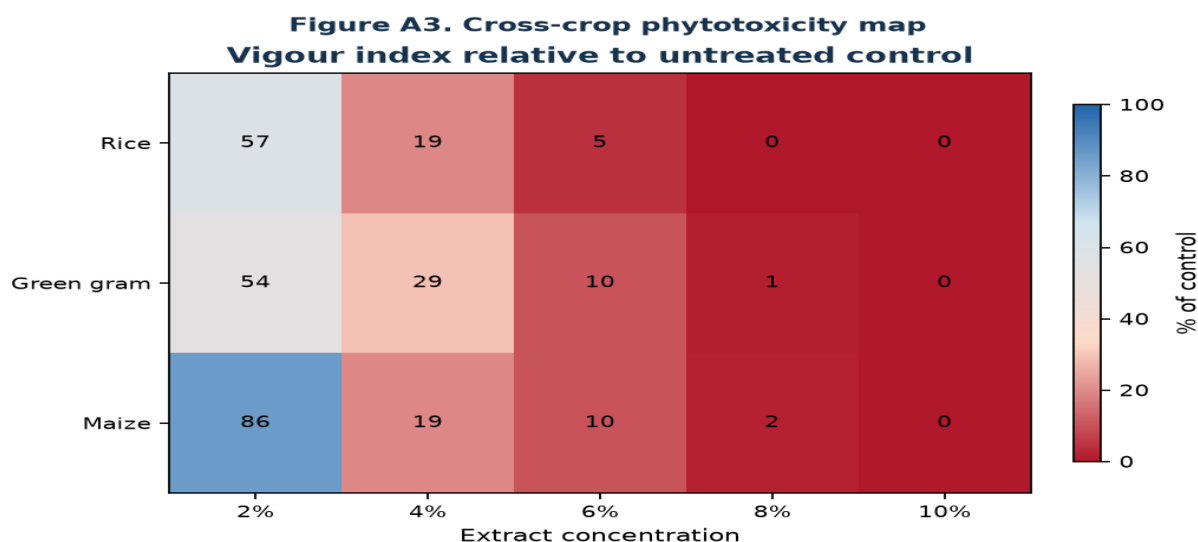


Figure A3. Vigour index expressed as a percentage of the untreated control across crop species and extract concentrations.

4. DISCUSSION

The results support the hypothesis that *Parthenium* leaf extract produces a concentration-dependent inhibition of crop establishment. The pattern is consistent with earlier work showing that *Parthenium* extracts and residues suppress germination and seedling growth in cereals, pulses, and other cultivated species [5–8,10–12]. The progressive decline is compatible with increasing exposure to soluble allelochemicals and with cumulative interference in water uptake,

reserve mobilization, cell division, and elongation. The complete inhibition observed in rice and green gram at 8–10% indicates that the extract strength can cross a threshold beyond which seedling emergence is no longer recoverable during the assay period.

Maize appeared comparatively tolerant at the germination endpoint, but this tolerance was incomplete. At 10%, one-fifth of maize seeds germinated, yet the resulting seedlings had almost no radicle development and a vigour index of only 10. This distinction is important for risk assessment: a residue may not completely prevent emergence but may still produce seedlings incapable of effective soil exploration. The crop ranking therefore depends on the response variable. Germination suggested greater maize tolerance, while radicle elongation showed severe injury in all crops at higher concentrations.

Radicle sensitivity was consistent across crops and concentrations. The root is the first organ to interact with the aqueous extract and is responsible for anchorage and early acquisition of water and nutrients. The observed radicle suppression is compatible with the activity of parthenin and phenolic acids reported in *Parthenium* tissues [4,7,8]. It also explains why vigour index declined more steeply than germination at intermediate concentrations. For agronomic management, this suggests that residue placement and the timing of crop sowing relative to weed removal may be as important as the total amount of biomass present.

The experiment was intentionally controlled, which improves treatment discrimination but limits direct extrapolation to soil systems. Soil adsorption, microbial degradation, rainfall, extract dilution, residue depth, and crop genotype can modify exposure. The assay also used a single leaf source and early seedling endpoints. Field validation should therefore examine residue rates, soil type, time after incorporation, and crop stand establishment under realistic moisture regimes. Nevertheless, the consistent response across three crops and multiple endpoints provides strong evidence that fresh or incompletely decomposed *Parthenium* biomass should not be placed in direct contact with germinating crop seed.

5. CONCLUSIONS AND PRACTICAL IMPLICATIONS

Aqueous *Parthenium* leaf extract strongly inhibited germination, root and shoot elongation, dry matter production, and vigour of rice, green gram, and maize. The response was concentration dependent, and radicles were consistently more sensitive than plumules. Rice and green gram were completely inhibited at 8–10% in the final observations, while maize retained limited germination at 10% but exhibited almost complete loss of early growth. The results support a precautionary management strategy: *Parthenium* biomass should be removed before seed set and should not be used as surface mulch, fresh amendment, or poorly stabilized compost near germinating crops. Where recycling is desired, the biomass should undergo a validated composting or vermicomposting process and the finished product should be screened with a crop bioassay before field application.

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