

Comparative Biochemical and Phytotoxic Effects of *Prosopis juliflora* and *Morus alba* Methanolic Extracts on the Germination and Burrowing of Radish Plants

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ABSTRACT

This study investigated the phytotoxic, toxicological, and phytochemical aspects of the methanolic extracts of *Prosopis juliflora* and *Morus alba*. Phytotoxic activity was measured using radish (*Raphanus sativus*) seed germination and root growth inhibition assays, whereas toxicity was tested using Indian night crawlers (*Perionyx excavatus*). Both extracts had strong, concentration-dependent inhibitory effects on seed germination and seedling growth. In *P. juliflora*, root growth inhibition increased from 12.63% at 10 ppm to 67.70% at 10,000 ppm, whereas the germination index decreased from 46.64% in the control to 29.54% at 10,000 ppm. Similarly, *M. alba* demonstrated greater phytotoxicity, with root inhibition increasing from

12.20% to 76.66% and the germination index decreasing from 46.12% to 28.11% across the same dose range. The extract concentration significantly affected root inhibition and the germination index ($P < 0.001$). Toxicity tests revealed that the mortality rate of Indian night crawlers increased considerably with increasing extract concentration, with *P. juliflora* having greater toxic effects than *M. alba* did ($F = 20.167$, $P = 0.001$). Both species contained alkaloids, flavonoids, saponins, coumarins, and phenols, but no tannins were detected through qualitative phytochemical screening. The findings show that both plant species have strong allelopathic and toxicological effects because of their diverse secondary metabolite compositions, emphasizing their ecological importance and possible applications in natural weed management.

Keywords: Allelopathy, *Prosopis juliflora*, *Morus alba*, Phytotoxicity, Seed Germination, Root Growth Inhibition, *Perionyx excavatus*, Phytochemical Screening

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Phytotoxic, Toxicological and Phytochemical Evaluation of *Prosopis juliflora* and *Morus alba* Methanolic Extracts

Both extracts exhibited concentration-dependent phytotoxicity and toxicity due to rich secondary metabolites with potential for natural weed management.

PLANT SOURCES

Prosopis juliflora



Morus alba

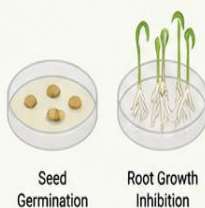


Methanolic
Extraction

EXPERIMENTAL DESIGN

Phytotoxicity Assays

Raphanus sativus (Radish)



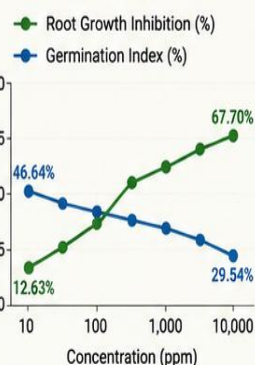
Toxicity Assay

Perionyx excavatus
(Indian night crawler)



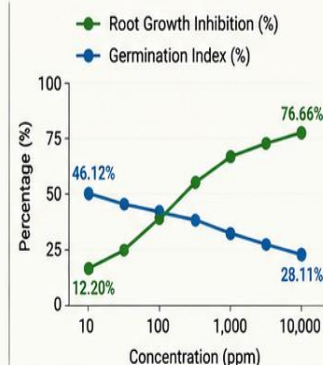
PHYTOTOXIC EFFECTS (Concentration dependent)

Prosopis juliflora



- Root inhibition: 12.63% (10 ppm) → 67.70% (10,000 ppm)
- Germination index: 46.64% (Control) → 29.54% (10,000 ppm)

Morus alba



- Root inhibition: 12.20% (10 ppm) → 76.66% (10,000 ppm)
- Germination index: 46.12% (Control) → 28.11% (10,000 ppm)

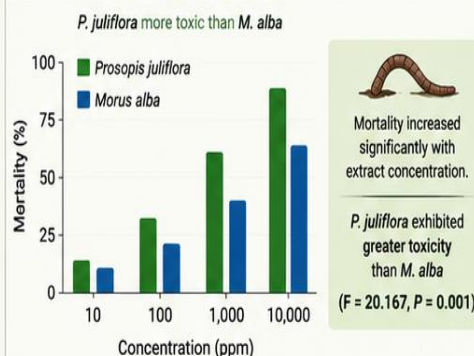


Extract concentration had a highly significant effect on root inhibition and germination index ($P < 0.001$)

QUALITATIVE PHYTOCHEMICAL SCREENING

Phytochemicals	<i>Prosopis juliflora</i> Extract	<i>Morus alba</i> Extract
Alkaloids	+	+
Flavonoids	+	+
Saponins	+	+
Coumarins	+	+
Phenols	+	+
Tannins	—	—
+ Present — Absent		

TOXICOLOGICAL EFFECTS (Indian night crawler mortality)



KEY TAKEAWAY



Both plant extracts strongly inhibit seed germination and root growth in a concentration-dependent manner.



Both extracts are toxic to Indian night crawlers; *P. juliflora* shows higher toxicity.



Presence of alkaloids, flavonoids, saponins, coumarins and phenols contributes to these bioactivities.



These findings support their ecological importance and potential use in natural weed management.



CONCLUSION: *Prosopis juliflora* and *Morus alba* methanolic extracts possess potent allelopathic and toxicological properties attributable to diverse secondary metabolites, highlighting their potential as eco-friendly bioherbicidal agents.

Graphical abstract for Comparative Biochemical and Phytotoxic Effects of *Prosopis juliflora* and *Morus alba* Methanolic Extracts on Radish Seed Germination and Burrowing

Introduction

Plants produce a wide range of secondary metabolites that mediate ecological interactions, protect against biotic and abiotic challenges, and control different physiological processes. Many of these bioactive substances have allelopathic effects, which affect the germination, growth, and development of nearby plant species (Twaij & Hasan, 2022). *P. juliflora* started from Peru and was found in northern South America, the southern United States and Mexico America during dry years. Many other dry tropical regions, including Africa, Australia, Southeast Asia, northeastern Brazil, and the Indian subcontinent, are known to contain *P. juliflora*. *P. juliflora* is present in India but is clearly present in the second 50% of the nineteenth century (Twaij & Hasan, 2022; Arias-Gómez et al., 2023).

This plant has become invasive in many locations due to its rapid growth, copious seed production, and capacity to adapt to harsh environmental conditions (Shaheryar et al., 2025). *P. juliflora* was introduced to Pakistan to stabilise sand dunes, and it has subsequently spread extensively over Sindh, Punjab, and Balochistan (Batoool et al., 2025; Qureshi, 2025). The plant's medical and ecological importance is ascribed to its richness of biologically active chemicals, such as flavonoids, alkaloids, phenols, tannins, and saponins (Sharma et al., 2022; Elshafie et al., 2023; El-Saadony et al., 2025).

P. juliflora has been shown in earlier research to have antibacterial, antifungal, antioxidant, anticancer, antiprotozoal, and phytotoxic properties (de Lemos et al., 2023; Afaq et al., 2024; Khalid et al., 2024). Strong allelopathic potential is indicated by the high quantities of inhibitory chemicals found in *P. juliflora* leaves, which can hinder the germination of seeds and the growth of seedlings of other plant species (Abbas et al., 2023; Bibi et al., 2023). Its invasive success in numerous habitats may be attributed to these phytotoxic characteristics (Miletić et al., 2026).

White mulberries, or *Morus alba* L., are native to China and were later brought to numerous regions of the world for horticultural and sericultural uses (Paniagua-Zambrana et al., 2025). Flavonoids, phenolic acids, alkaloids, glycosides, resveratrol derivatives, and enzyme inhibitors with a variety of pharmacological properties are among the many bioactive components found in mulberries (Fatima et al., 2024). A biological phenomenon known as allelopathy occurs when plants release chemicals into their surroundings that affect the growth and development of nearby organisms.

These allelochemicals may affect physiological functions, nutrient intake, root elongation, and seed germination (Wang et al., 2025). One of the best solvents for removing secondary metabolites from plant tissues is methanol. Alkaloids, flavonoids, phenols, coumarins, tannins, glycosides, and saponins are frequently found in methanolic extracts and may contribute to biological and phytotoxic activities (Khade et al., 2023).

Earthworms, particularly Indian night crawlers (*Pheretima posthuma*), are important bioindicators of soil quality and toxicity. They are extensively used in ecological and toxicological research due to their high sensitivity to hazardous substances found in soil (Singh & Fatima, 2022). The current study aimed to investigate the biochemical composition and phytotoxic effects of methanolic extracts of *Prosopis juliflora* and *Morus alba* on radish seed germination and Indian night crawlers. To further comprehend their allelopathic and ecological significance, the phytochemical components of both species were investigated, as well as their inhibitory effects on biological responses and seed germination.

Materials and methods

Phytotoxic potential of the two invasive species

Radish seed germination assay

The seed germination assay was executed as described by Camper and Turker (2002).

Determination of root length inhibition

The radish seeds were cleaned with one percent mercuric chloride. The filter paper from the Whatman No. 1 channel was fixed on Petri plates, and approximately five ml of each and every concentrate fixation (10, 100, 500, 1000 and 10000 ppm) was used individually. Five ml of refined H₂O was added after the disappearance of dissolvable H₂O, after which 10 radish seeds were placed on each Petri dish, which were subsequently fixed and replaced at 23±2 °C. The length of the roots was restrained for one, three and five days. The rate of development restraint by the concentrates was estimated by the following connection: %age inhibition of growth=100 (PC-PT)/PC, where PC and PT communicate to the length of the roots for the control and treatment groups, respectively.

Determination of the germination index

This section of the purpose was parallel to that of the prior purpose, aside from the concentrated obsessions and the number of seeds. Three distinct focuses (100, 1000

and 10000 ppm) and one hundred radish seeds were consumed. The seeds that were germinated were tallied every day for as long as five days. The degree of germination was determined as follows: $N1, N2, N3 - Nn = \text{Day 1 Germinated seed percentage} - n$. Every experiment was completed 3 times. The outcomes are presented as the means of 3 duplicates $\pm$ the standard deviation of triplicate investigations.

Sandwich method

The phytotoxicity of the plant leachates was determined by the Sandwich method following the convention of Fujii et al. (2004). The agar (0.5% w/v) was autoclaved and stored at 121°C for 15 minutes. The material of the plants was ten, thirty and fifty mg delicately sloped into the shafts of a 6-well multiwell plate. By using a pipette, the first layer of agar (5 ml) was combined, and the dissolved material of the rose plant was acceptable for gelation, over which the second layer of agar was associated. In each dish, five lettuce seeds were set beyond the agar. With the help of many dishes, they were protected from light and kept in a hatchery at room temperature. The radicle and hypocotyl were prominent after seventy-two hours for each and every plant. The rate of development restraint in the hypocotyl and roots under every action was assessed as follows: $\% \text{age growth inhibition} = 100 (PC - PT) / PC$, where PT and PC refer to the root/hypocotyl length of the control and management, respectively.

Assessment of the Toxicity of Indian Night Crawlers

Healthy adult Indian night crawlers (*Perionyx excavatus*) were acclimatized under laboratory conditions before the experiment. Methanolic extracts of *Prosopis juliflora* and *Morus alba* were prepared at concentrations of 25%, 50%, and 100%, while distilled water served as the control. Ten earthworms were exposed to each treatment in triplicate for 72 hours. Mortality and behavioral changes were recorded, and the mortality percentage was calculated to evaluate the toxic effects of the extracts.

Phytochemical analysis of plant extracts

Test for alkaloids

Mayer's reagent: In sixty ml of water, mercuric chloride (0.356 g) was broken up, and potassium iodide (5 g) was disintegrated in 20 ml of water. The two preparations were diverse, and the volume was also 1000 ml with refined H₂O. Dragendorff's reagent: Solution A: In 80 ml of refined water, basic tartaric corrosive (20 g) and bismuth nitrate (1.7 g) were broken up. Arrangement B: In 40 ml of refined water, potassium iodide (16 g) was disintegrated. Arrangements A and B were mixed at a

1:1 ratio. After 8 ml of 1% HCl was added, the sample was separated and warmed, and the plant was removed (0.5 g). The filtrate was treated independently with Dragendorff's reagent and Mayer's reagent. Precipitation and turbidity were observed to affect the proximity of the alkaloids.

Test for flavonoids

Separate plants (0.5 g) were mixed or shaken with petroleum-ether to remove the greasy materials. The remaining material was broken up in 20 ml of 80% ethanol and separated. Afterward, the filtrate was mixed with four ml of 1% KOH. Dim yellow shading was used to indicate the presence of flavonoids.

Test for coumarins

Separate plants (0.5 g) were placed in a small test tube and secured with filter paper moistened with 1 N NaOH. The test cylinder was put in bubbling H₂O for several minutes. The filter paper was detached and scanned for yellow fluorescence under UV light to demonstrate the nearness of the phytochemical coumarins.

Test for phenols

Concentrates of plants were treated with three to four drops of newly arranged FeCl₃. The appearance of light blue dusky shading reflected the proximity of the phenols.

Test for saponins

Plant removal (0.5 g) was broken down in a test tube and in bubbling water, which was then allowed to shake and cool together. Foam formation was observed to demonstrate the nearness of the saponins.

Test for tannins

In 20 ml of refined water, the plant removed (0.5 g) was bubbled in a test tube and sifted. To the filtrate, FeCl₃ (0.1%) was added. The presence of tannish green or bluish black indicated the presence of tannins. Test for glycosides. The concentrate (0.5 g) was shattered down in a rigid acidic (2.0 ml) corrosive solution comprising 1 drop of FeCl₃ (0.1%), after which it was rested with concentrated H₂SO₄ (1.0 ml). A darker circle at the boundary indicates the presence of glycosides.

Results

Assessment of the Phytotoxicity of *Prosopis juliflora*

Root length inhibition

Different doses of *Prosopis juliflora* extract substantially affected radish seedling root growth (Table 1). Group A presented the greatest mean root growth (67.70 mm) at

10,000 ppm, which was significantly different from that in all the other treatments. As the extract concentration decreased, root growth gradually decreased. Group B seedlings treated with 1000 ppm had a mean root length of 46.94 mm. At 500 ppm (34.65 mm) and 100 ppm (26.77 mm), intermediate root growth levels were detected; these values were categorized as B, C and C, D, respectively. Group D had the greatest inhibitory effect on radish root development, with the lowest mean root growth (12.63 mm) occurring at 10 ppm.

The lowest inhibitory effect on root length among all five concentrations (10000, 1000, 500, 100, and 10 ppm) was observed at 12.63%. After that, the inhibition of root length gradually increased with increasing concentrations of methanol, such as 100, 500, 1000, and 10000 ppm, which resulted in root length inhibition (26.76%, 34.65%, 46.94% and 67.70%, respectively). After statistical analysis, significant P values were obtained. This clearly clarified the level of toxicity of the *Prosopis juliflora* plant extract. High root length inhibition was observed at 10,000 ppm, and the lowest root length inhibition occurred under the control condition and then at 10 ppm. A general trend toward increased phytotoxicity with increasing extract concentration was observed (Figure 1).

Table 1: Effect of *Prosopis juliflora* extracts on root growth in radish seedlings

Concentrations	No of replicates	Mean	StDev	Grouping
10,000ppm	3	67.70	14.25	A
1000ppm	3	46.94	2.12	B
500ppm	3	34.65	1.450	B,C
100ppm	3	26.767	4.04	C,D
10ppm	3	12.63	2.31	D

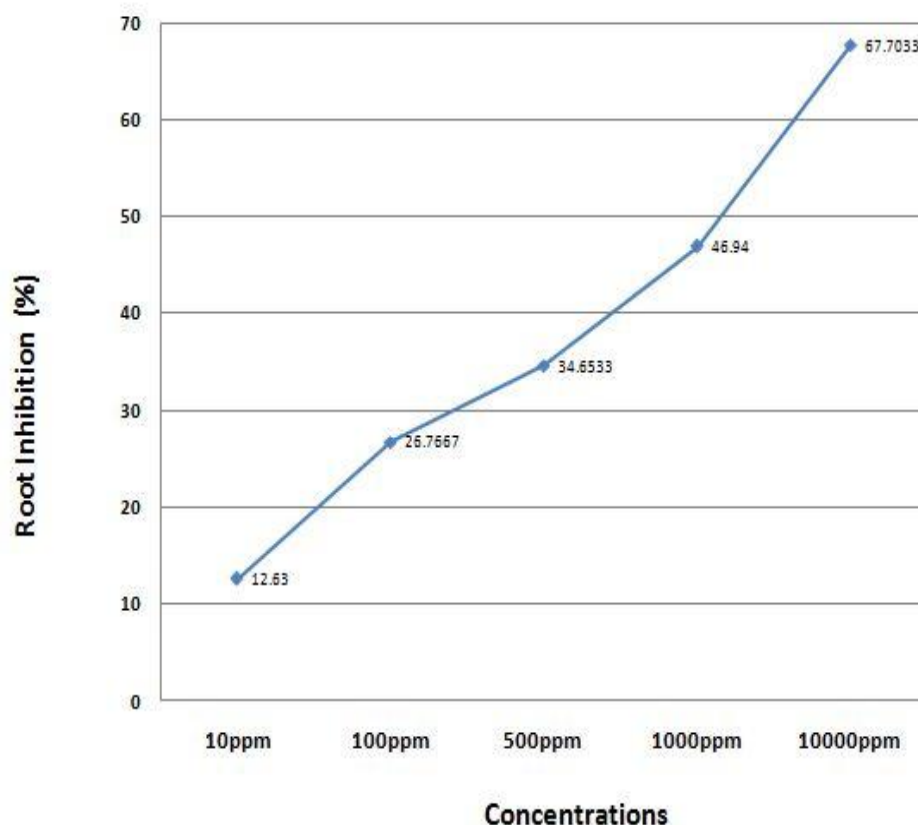
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analysis of variance (ANOVA) ($F = 28.24$, $P < 0.001$; Table 2). While the mean square error was 46.28, the concentration factor explained a sum of squares of 5228.2, with a mean square value of 1307.05. The extremely significant P value suggests that variations in the concentrations of the *Prosopis juliflora* extract, rather than experimental error, were the main cause of the variability in root growth. These results show that radish root growth and inhibitory responses were significantly affected by the extract concentration.

Table 2: Root inhibition of *Prosopis juliflora* (analysis of variance)

Source	DF	SS	MS	F-VALUE	P – VALUE
Concentratio ns	4	5228.2	1307.05	28.24	0.00
Error	10	462.8	46.28		
Total	1	569			

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Germination Index

The dosage of *Prosopis juliflora* extract had a significant effect on the radish seed germination index (Figure 1). At the lowest concentration (10 ppm), the germination index was greatest (46.64%), followed by 41.25% at 100 ppm and 35.78% at 1000 ppm. The germination index decreased to 29.54% at the maximum concentration (10,000 ppm), indicating an additional reduction. Overall, as the *P. juliflora* extract concentration increased, the germination index decreased in a concentration-dependent manner. Compared with that at 10 ppm, the germination index at 10,000 ppm decreased by approximately 36.7%, suggesting that higher extract concentrations have a significant negative effect on seed germination and early seedling vigor. These results imply that the germination performance of radish is significantly affected by concentrated *P. juliflora* extracts.

Different doses of *Prosopis juliflora* extract substantially affected the radish seed germination index (Table 3). Group A was assigned to the control treatment (0 ppm), which had the greatest germination index (46.64%) and was statistically superior to the other extract-treated groups. The germination index gradually decreased as the extract concentration increased. The germination index decreased to 41.25% (group B) at 100 ppm; additional decreases were noted at 1000 ppm (35.78%; group C) and 10,000 ppm (29.54%; group D). The clear grouping pattern shows notable variations across all dosage levels, indicating that the extract inhibits seed germination and seedling vigor in a concentration-dependent manner.

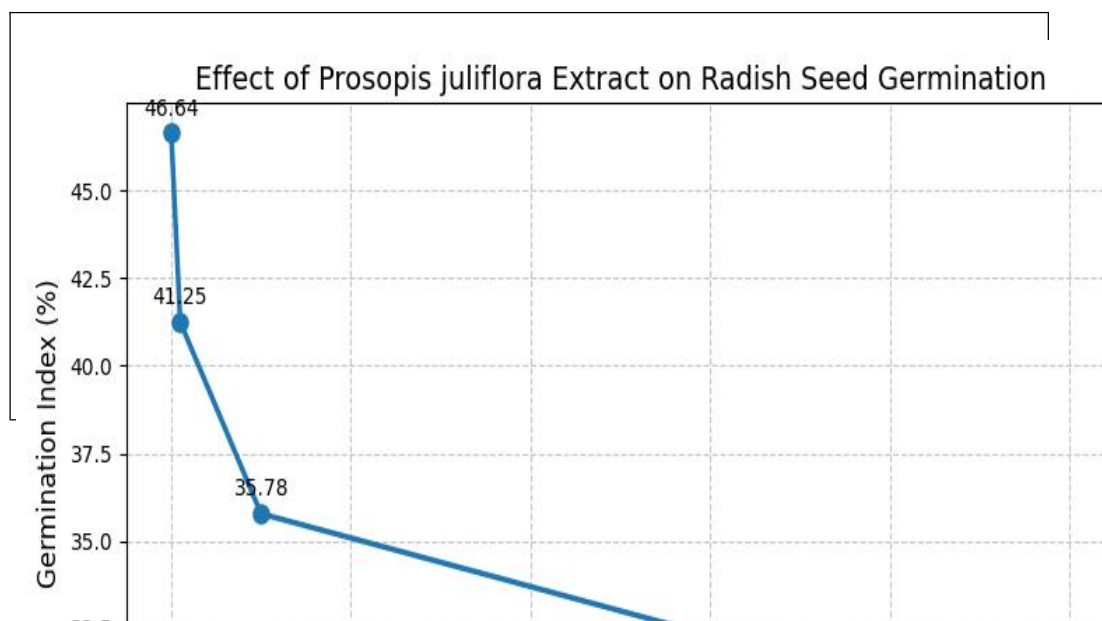
The concentration of *P. juliflora* extract had a highly significant effect on the germination index according to analysis of variance (ANOVA) ($F = 31.84$, $P < 0.001$; Table 4). While the erroneous mean square was just 5.12, the concentration factor explained a sum of squares of 488.72 and a mean square of 162.91. The highly significant P value suggests that changes in extract concentration, rather than chance, were the main cause of the observed fluctuations in the germination index. These findings show that the considerable allelopathic activity of *P. juliflora* extract is demonstrated by the severe suppression of radish seed germination performance at increasing doses.

Table 3: Effect of *Prosopis juliflora* extracts on the radish seed germination index

Concentration	No. of replicates	Mean	StDev	Grouping
0 ppm	3	46.64	1.62	A
100 ppm	3	41.25	2.34	B
1000 ppm	3	35.78	2.18	C
10,000 ppm	3	29.54	2.56	D

Table 4: Germination index of *Prosopis juliflora* (Analysis of Variance)

Source	DF	SS	MS	F Value	P Value
Concentrations	3	488.72	162.91	31.84	0.000
Error	8	40.92	5.12		
Total	11	529.64			



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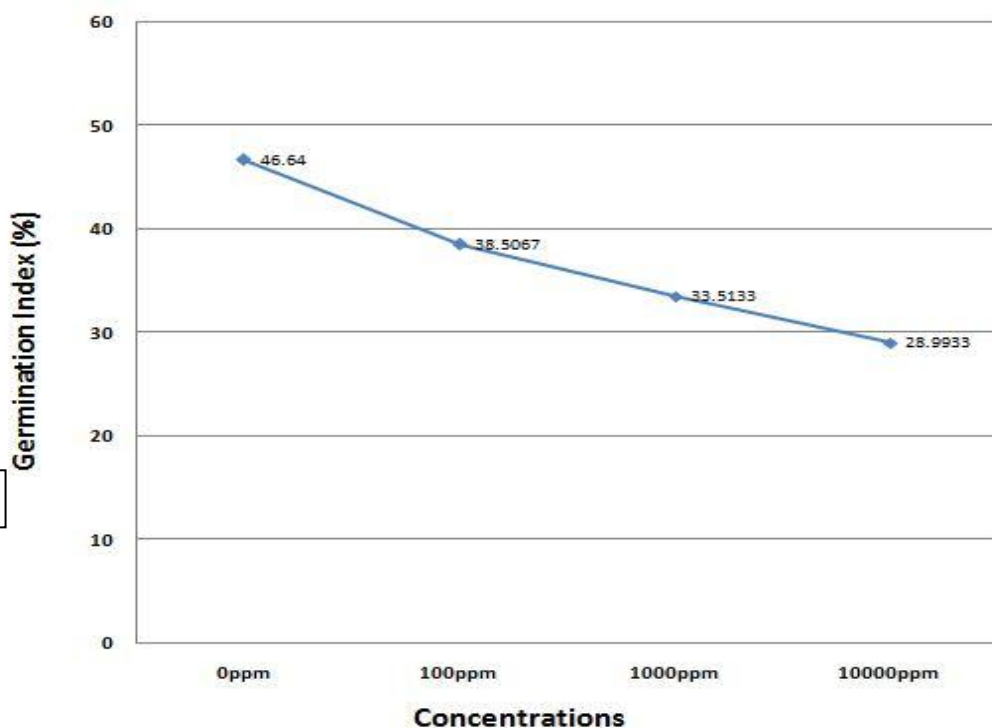
Figure 2: Effect of *Prosopis juliflora* extract on radish seed germination

Germination Index in *Prosopis juliflora*

In the second part of the experiment, the effects of 3 different concentrations of each extract (100, 1000, and 10000 ppm) on the germination index of the seeds were observed. The rate of seed germination was high (46.64%) at 0 ppm (Figure 3b).



a



b

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Figure 3 (3a–3b): (3a) Radish seed germination during the seed germination bioassay (3b) Reduction in the germination index of radish seeds with different concentrations of *Prosopis juliflora* extract

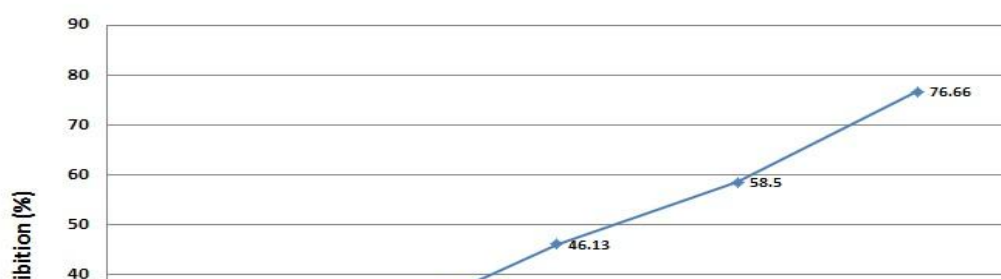
Root Inhibition

Morus alba inhibited root growth in radish seedlings when extracts from the plants were applied to the plants. The maximum inhibition of root growth was displayed by the extract of methanol at a concentration of 10,000 ppm (76.66%). Different concentrations were applied, such as 1000 ppm, 500 ppm, 100 ppm and 10 ppm. At 1000 ppm, the root length inhibition was 58.50%. Differences between root length inhibition at 10,000 ppm and 1000 ppm can be seen. Similarly, the differences in root length inhibition caused by 500 ppm and 1000 ppm were 46.1% and 58.50%, respectively (Figure 4a). The root length inhibition at 100 ppm and 10 ppm was 29.72% and 12.2%, respectively. It is clear from the assumption that with the guide of expanding the concentrate fixation, the level of root length hindrance also increased. This finding highlights the toxicity of *Morus alba*. There is a progressive decrease in poisonous quality when the focus decreases from 10,000 ppm to 10 ppm.

Germination Index in *Morus alba*

Different quantities of *Morus alba* extract substantially affected the radish seed germination index. The control treatment (0 ppm) resulted in the greatest germination index (45.12%). The germination index decreased with increasing extract concentration, reaching 39.40% at 100 ppm, 34.07% at 1000 ppm, and 28.11% at 10,000 ppm. Compared with that in the control treatment, the germination index in the treatment group decreased by almost 37.7%.

Overall, the findings revealed that *M. alba* extract clearly inhibited seed germination and early seedling vigor in a concentration-dependent manner. The gradual decrease in the germination index with increasing extract concentration indicates that *M. alba* allelochemicals negatively affect radish seed germination (Figure 4b).



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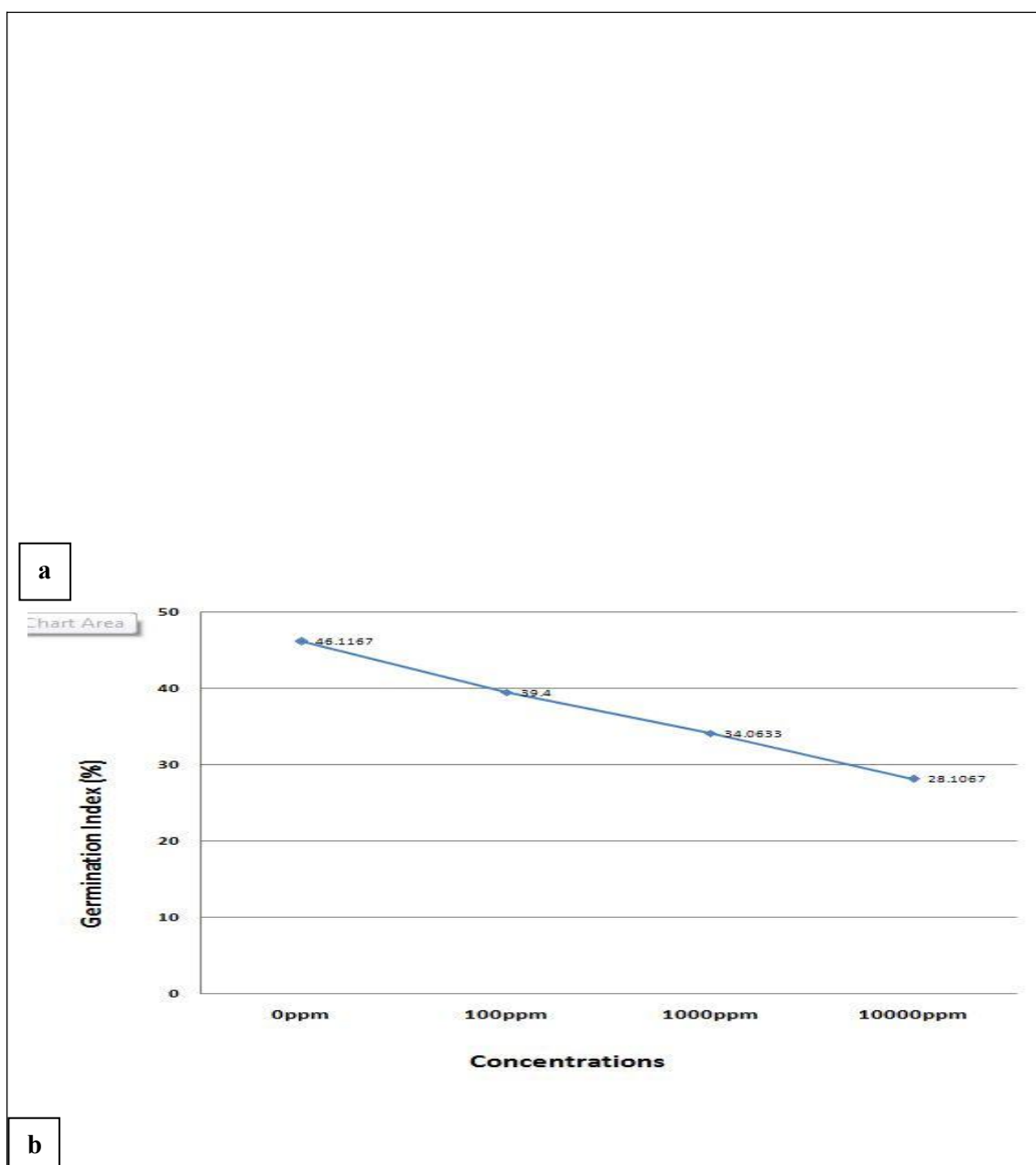


Figure 4 (4a–4b): (4a) Percentage root inhibition of radish seedlings with different concentrations of *Morus alba* extract. (4b) Reduction in the germination index of radish seeds with different concentrations of *Morus alba* extract.

The concentration of *Morus alba* extract had a substantial effect on radish seedling root growth (Table 5). Group A had the greatest mean root growth (76.66 mm) at

10,000 ppm, which was significantly different from that in all the other treatments. As the extract concentration decreased, root growth gradually decreased, with mean values of 58.50 mm at 1000 ppm (group B), 46.10 mm at 500 ppm (group C), and 29.70 mm at 100 ppm (group D). Group E was given the lowest root growth (12.20 mm) at 10 ppm. The unique grouping pattern showed notable variations across all concentration levels, suggesting that radish root growth was significantly affected by the concentration of *M. alba* extract.

Table 5: Effects of *Morus alba* extracts on root growth in radish seedlings

Concentration	No of replicates	Mean	StDev	Grouping
10,000ppm	3	76.66	5.65	A
1000ppm	3	58.5	3.96	B
500ppm	3	46.1	2.68	C
100ppm	3	29.7	5.26	D
10ppm	3	12.2	2.49	E

The quantities of *M. alba* extract varied significantly according to analysis of variance (ANOVA) ($F = 105.45$, $P < 0.001$; Table 6). While the mean square error was just 17.73, the concentration treatment resulted in a sum of squares of 7476.5, with a mean square of 1869.12. The extremely high F value and highly significant P value indicate that variations in extract concentration, not experimental error, were the main cause of the variance in root development. These findings show that radish root growth is strongly and concentration-dependently impacted by *M. alba* extract, indicating significant allelopathic activity.

Table 6: Effect of *Morus alba* extract on root inhibition (analysis of variance)

Sour ce	DF	S S	MS	F-VALUE	P -VALUE
Concentratio ns	4	7476.5	1869. 12	105. 45	0.0 00
Error	1 0	177.3	17.73		
Total	1	7653.7			

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The effects of varying doses of *Morus alba* leaf extract on the radish seed germination index are displayed in Table 7. The control treatment (0 ppm) resulted in the greatest germination index (46.12%), indicating normal germination and seedling vigour in the absence of the extract. The germination index progressively decreased as the *M. alba* extract content increased. The germination index decreased to 39.40% at 100 ppm, 34.06% at 1000 ppm, and 28.11% at 10,000 ppm. The grouping results (A, B, C, and D) show that there were significant differences between each therapy. The steady decrease in the germination index with increasing extract concentration shows that *M. alba* includes allelochemicals that negatively affect seed germination and early seedling growth.

Table 7: Effect of *Morus alba* extracts on the radish seed germination index

Concentrations	No of replicates	Mean	StDev	Grouping
0ppm	3	46.117	1.550	A
100ppm	3	39.40	2.75	B
1000ppm	3	34.06	2.15	C
10,000ppm	3	28.11	2.44	D

The results of the analysis of variance (ANOVA) for the germination index of radish seeds treated with various concentrations of *M. alba* extract are shown in Table 8. An F value of 34.38 and a P value of 0.000 ($P < 0.001$) indicated that the concentration effect was extremely significant. The treatment sum of squares (529.69) was much greater than the error sum of squares (41.08), indicating that variations in extract concentration accounted for the majority of the variation in the germination index. The strong influence of the extract was further confirmed by the fact that the treatment mean square (176.56) was significantly greater than the error mean square (5.14). These findings support the strong allelopathic activity of *M. alba* extract, as increasing concentrations substantially affected the radish seed germination index.

Table 8: Germination index of *Morus alba* (analysis of variance)

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Source	DF	SS	MS	F-VALUE	P-VALUE
Concentrations	3	529.69	176.564	34.38	0.000
Error	8	41.08	5.135		
Total	11	570.77			

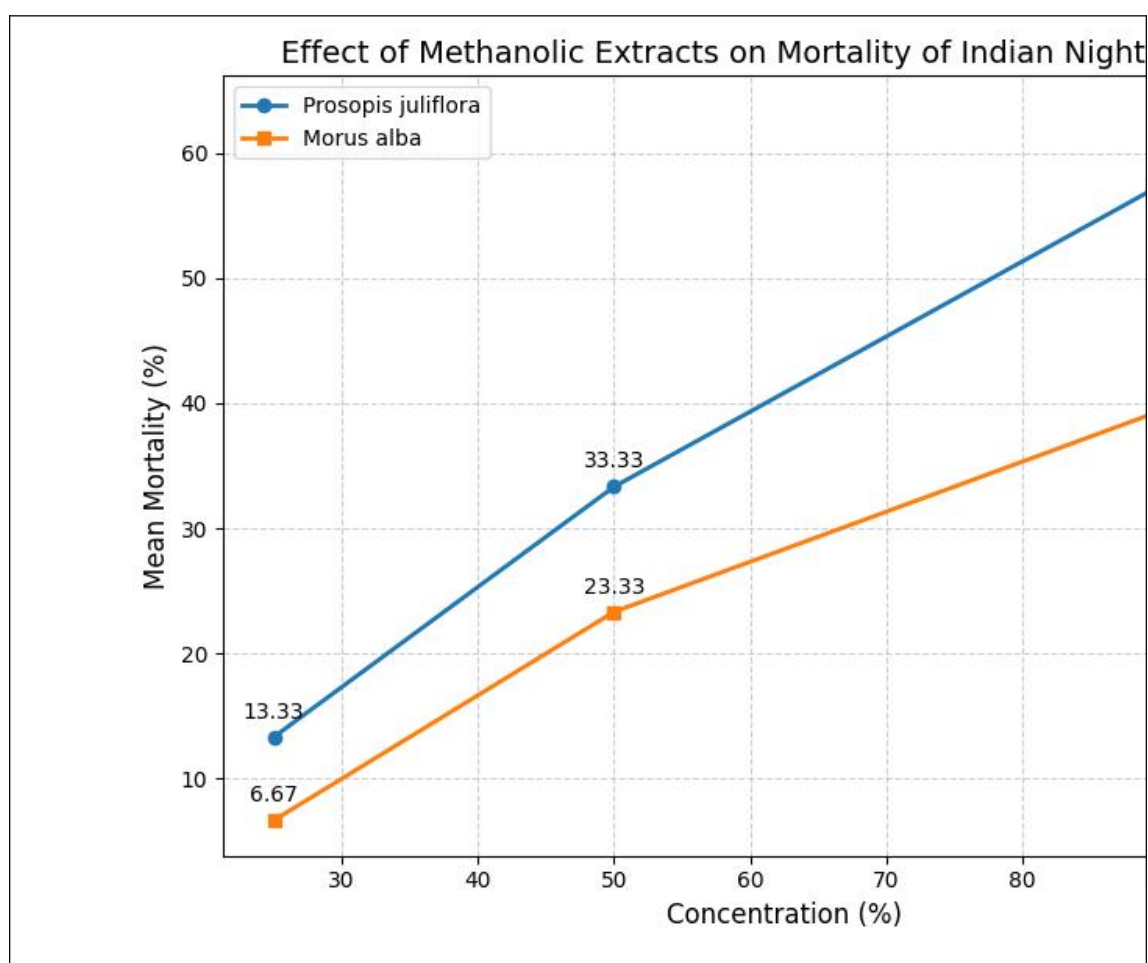


Figure 7: Effect of *Prosopis juliflora* and *Morus alba* Methanolic Extracts on the Mortality of Indian Night Crawlers

Both extract type and concentration had a significant effect on Indian night crawler mortality according to two-way ANOVA. Concentration had a highly significant effect on mortality ($F = 85.167$, $P < 0.001$), whereas extract type had a substantial effect ($F = 20.167$, $P = 0.001$). Both extracts resulted in comparable mortality response patterns across concentrations, but the interaction between extract type and concentration was not significant ($F = 2.167$, $P = 0.157$). In general, death increased

as the concentration increased, with *Prosopis juliflora* causing more mortality than *Morus alba* did.

Table 9: ANOVA test for the effects of *Prosopis juliflora* and *Morus alba* Methanolic Extracts on the Mortality of Indian Night Crawlers

Source of Variation	DF	SS	MS	F Value	P Value
Extract	1	672.222	672.222	20.167	0.001
Concentration	2	5677.778	2838.889	85.167	0.000
Extract × Concentration	2	144.444	72.222	2.167	0.157
Error	12	400.000	33.333		
Total	17	6894.444			

Several bioactive substances were found in the methanolic extracts of **Prosopis juliflora** and *Morus alba* according to a qualitative phytochemical investigation (Table 4.10). Alkaloids, flavonoids, saponins, coumarins, and phenols were found in both plant extracts, suggesting a similar phytochemical composition. Nevertheless, neither of the extracts contained any tannins.

The presence of phenolic substances, alkaloids, flavonoids, saponins, and coumarins indicates that these extracts contain a wide variety of secondary metabolites that could support their allelopathic and biological effects. The negative effects on earthworm mortality, seed germination, and seedling growth are likely related to the presence of these phytochemicals. Overall, the findings suggest that the significant bioactive components found in both *P. juliflora* and *M. alba* may be responsible for their ecological and toxicological effects.

Table 10: Qualitative phytochemical analysis of *Prosopis juliflora* and *Morus alba*

Phytochemical	<i>Prosopis juliflora</i> extract	<i>Morus alba</i> extract
Alkaloids	+	+
Flavonoids	+	+
Saponins	+	+
Tannins	-	-
Coumarins	+	+

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Phenols	+	+
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Discussion

Prosopis juliflora Inhibits Root Length

The results of the current investigation revealed that the *Prosopis juliflora* methanolic extract considerably and concentration-dependently suppressed radish root development. Strong phytotoxic activity was demonstrated by the increase in root inhibition from 12.63% at 10 ppm to 67.70% at 10,000 ppm. Bibi et al. (2023) reported similar results, indicating that *P. juliflora* extracts inhibited the growth of crop plants. Phenolic chemicals, flavonoids, alkaloids, and saponins that disrupt cell division, nutrient absorption, and membrane stability during seedling development may be responsible for these inhibitory effects (Valiño et al., 2023; Guedes et al., 2024).

Because roots are directly exposed to harmful substances discharged into the environment, root extension is regarded as one of the most sensitive markers of allelopathic interference (Ebana & Okuno, 2022). The notable decrease in root growth in this study indicates that the extract interfered with the regular physiological processes necessary for root development. According to earlier research, phenolic substances can limit root elongation by reducing water intake and inhibiting mitotic activity (de Almeida et al., 2024).

Additionally, a dose-dependent phytotoxic reaction is indicated by a steady increase in inhibition with increasing extract concentration. Many allelopathic plants have been shown to exhibit this concentration-dependent inhibition, which is thought to be a sign of chemical interference between plant species (Dang Xuan et al., 2025).

Effects of *Prosopis juliflora* on the Germination Index

As the *P. juliflora* extract concentration increased, the radish seed germination index

dramatically decreased. A significant negative effect on seed germination and early seedling vigor was demonstrated by the decrease from 46.64% in the control treatment to 29.54% at 10,000 ppm. Several allelopathic species with high concentrations of phenolic chemicals and alkaloids have been shown to exhibit similar decreases in germination (Vale et al., 2026; Xu et al., 2023).

Enzyme activation, food reserve mobilization, and hormone modulation are only a few of the physiological and biochemical mechanisms that control seed germination (Ambhore et al., 2025). Allelochemicals can disrupt these processes by altering gibberellin-mediated growth responses, decreasing respiration rates, and blocking α -amylase activity. As a result, treated seeds frequently show delayed germination and decreased

The reduction in the germination index in this study suggests that *P. juliflora* contains substances that can inhibit seed establishment. By lessening competition from nearby plants and promoting species expansion in invaded habitats, such inhibitory effects may offer ecological benefits to the species (Baibout et al., 2022).

***Morus alba* Inhibits Root Length**

Radish root growth was considerably suppressed by *Morus alba* methanolic extracts; this inhibition increased from 12.20% at 10 ppm to 76.66% at 10,000 ppm. Mulberry leaves may contain extremely potent phytotoxic chemicals, as evidenced by the greater inhibitory effect observed for *M. alba* than for *P. juliflora*. Flavonoids, phenolic acids, derivatives of resveratrol, and other bioactive components have been found in *M. alba* tissues in earlier phytochemical studies (Xin et al., 2024).

Phenolic chemicals can change membrane permeability and prevent nutrient absorption, hindering root development (de Almeida et al., 2024). Compared with other plant tissues, roots frequently react more strongly since they are the first plant organs to be exposed to allelochemicals.

The results of the very significant ANOVA in the current study revealed that concentration was the main factor affecting root inhibition. Studies assessing the allelopathic effects of plant-derived extracts on crop seedlings have reported similar results (Chaves Lobón et al., 2023).

Effects of *Morus alba* on the Germination Index

As the concentration of *M. alba* extract increased, the radish seed germination index gradually decreased. The control treatment had the highest germination index, while

the 10,000 ppm treatment had the lowest value. This pattern illustrates how mulberry-derived allelochemicals impede seed germination.

Interference with the physiological processes required for seed activation and embryo growth may be the cause of the decrease in the germination index. Enzyme systems involved in the mobilization of stored proteins and carbohydrates during germination are known to be inhibited by phenolic compounds and flavonoids (Bradford & Hilhorst, 2023). As a result, the treated seeds had lower germination rates and poorer seedling growth.

The concentration-dependent decrease in the current study is in keeping with earlier findings showing the allelopathic effects of phenolic-rich plant extracts (Imarhiagbe et al., 2023). These results imply that, in addition to resource rivalry, *M. alba* may affect the composition of plant communities through chemical interactions.

Evaluation of Toxicity among Indian Night Crawlers

Because earthworms react quickly to harmful compounds in their environment, they are widely acknowledged as sensitive bioindicators of soil quality and environmental contamination (Edwards & Arancon, 2022). The mortality rate of Indian night crawlers in the current study increased dramatically as the amounts of both plant extracts increased, suggesting strong toxicological activity.

Phytochemicals that can interfere with cellular and physiological processes in soil organisms, such as alkaloids, saponins, and phenolic compounds, may be linked to the observed mortality (Nascimento-Gonçalves et al., 2026). Some of the previous ecotoxicological studies have reported similar toxic effects of plant secondary metabolites on earthworms (Alves et al., 2022).

Decomposition, nitrogen cycling, soil aggregation, and aeration are all significant ecological functions of earthworms. Reductions in their survival may therefore have an impact on ecosystem functioning and soil fertility. The findings of the current study indicate that even when these extracts have phytotoxic qualities, it is important to carefully consider how they can affect nontarget creatures in the ecosystem.

Comparative Toxicity of *Morus alba* and *Prosopis juliflora*

According to the results of the current study, compared with *Morus alba*, *Prosopis juliflora* killed more Indian night crawlers. These results imply that the bioactive chemical concentrations and potencies of the two species differ. According to earlier research, *P. juliflora* includes a number of physiologically active alkaloids and

phenolic components linked to poisonous and antibacterial properties (Atarama-Castillo et al., 2025).

The ability of *P. juliflora* to emit allelochemicals that inhibit rival species has often been cited as the reason for its invasive success (Baibout et al., 2022). The ecological significance of its secondary metabolites is thus further supported by the higher toxicity observed in this study. To identify the specific substances that cause earthworm death, more research is necessary.

Qualitative phytochemical analysis

Flavonoids are phytochemicals that are soluble in water and have anticancer, anti-inflammatory and antioxidant activities. Flavonoids are used to prevent some heart issues (Al-Khayri et al., 2022). Flavonoids are present fundamentally in entire parts of the plant heart wood, root, bark, sap wood leaf, flower and fruit (Roy et al., 2022). Alkaloids and their derivatives are utilized as essential agents for their antispasmodic, bactericidal and analgesic activities (Rajput et al., 2022). *P. juliflora* alkaloid-rich fractions are antibacterial and antifungal. Saponins are extensively scattered in nature and occur mainly in the plant kingdom. These compounds are commonly called nonvolatile exterior active composites and have bitter or sweet, emulsifying, foaming, pharmacological, hemolytic and medicinal properties, as well as insecticidal, molluscicidal and antimicrobial activities (Vasile et al., 2025). Phenols and phenolic components prevent platelets from clattering and have the ability to accumulate specific enzymes that are responsible for inflammation; thus, these compounds are immune enhancers, hormone modulators and antioxidants and are also used to prevent wounds and skin infections (Olas, 2022).

The plant is an ironic source of natural elements, specifically saponins, flavonoids and alkaloids. The biological and pharmacological activities of these compounds indicate the importance of the plant as a potential aspirant for the development of phytomedicines. In the maintenance of the current work, further investigations and analyses using chromatography and extraction for the purification and isolation of compounds that target alkaloids and flavonoids have already been conducted (Rajabiyan et al., 2025).

Flavonoids are also found in *Psidium guajava*, *Punica granatum*, *Morus alba*, *Fagonia cretica*, *Acacia nilotica* and *Ficus palmate*. Epidemiologic readings suggest that coronary heart disease is altered by dietary flavonoids. Alkaloids are also utilized

for medical purposes to reduce fever and headache. These compounds are credited for their analgesic and antibacterial properties.

Qualitative phytochemical analysis was performed on the methanol extract of both plant samples during the present investigation. Phytochemical screening of *Prosopis juliflora* confirmed the presence of saponins, alkaloids, coumarins and phenols, but at the same time, tannins were absent.

On the other hand, a phytochemical screening of the *Morus alba* plant revealed the presence of alkaloids, coumarins, saponins and phenols, but it also revealed that tannins were absent. The difference in the composition of our samples and those in the literature might be due to differences in conditions, particularly the genotype, origin, drying site, temperature and extraction process (Batiha et al., 2023).

Conclusion

The present study demonstrated that the methanolic extracts of *Prosopis juliflora* and *Morus alba* possess strong phytotoxic and toxicological activities. Both extracts strongly decreased radish seed germination and root growth in a concentration-dependent manner, with *M. alba* showing stronger root growth suppression (76.66%) than *P. juliflora* (67.70%) at 10,000 ppm. The germination indices were also significantly lower at higher extract concentrations, indicating allelopathic potential. Furthermore, both extracts induced considerable death in Indian night crawlers, with *P. juliflora* being more poisonous. Phytochemical research revealed the presence of alkaloids, flavonoids, phenols, coumarins, and saponins, which are most likely responsible for the reported biological properties. Overall, these findings indicate that *P. juliflora* and *M. alba* contain bioactive compounds that can influence plant growth and soil organisms, highlighting their ecological significance and possible utility as natural sources of bioherbicidal compounds.

Declarations

Ethics approval

All the protocols used in this study were approved by the Institutional Ethics and Guideline Committee of the University of Lahore, Lahore, Pakistan. All the experimental methods of this study followed all the appropriate guidelines and regulations.

Consent for publication

All the subjects gave their “informed consent” for the publication of details within the

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text (“informed consent”) to be published in the above Journal and Article. Written “informed consent” was obtained from all the authors for the publication of this manuscript.

Availability of data and materials

The data generated are provided within the manuscript and are available from the author upon reasonable request.

Competing Interests

All the authors declare that there are no competing interests.

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References

1. Ravi, R. and Krishnan, S., 2024. Invasive networks: An environmental history of the introduction of *Prosopis juliflora* to Banni grassland, India. *Geoforum*, 157, p.104144.
2. Twaij, B.M. and Hasan, M.N., 2022. Bioactive secondary metabolites from plant sources: types, synthesis, and their therapeutic uses. *International Journal of Plant Biology*, 13(1), pp.4-14.
3. Arias-Gámez, J.M., Linares-Perea, E., Vicente-Orellana, J.A. and Galán-de-Mera, A., 2023. Biogeographical relationships and diversity in the Peruvian flora reported by Hipólito Ruiz and José Pavón: vegetation, uses and anthropology. *Biology*, 12(2), p.294.
4. Shaheryar, M., Safiullah, D., Hayat, H.S., Shah, M.N., Akram, M.T., Iqbal, M.U., Hayat, A. and Naseem, M.A., 2025. Climate Change and Environmental Instability: The Rise of Invasive Species and Desertification. In *Navigating Climate Change: Impacts on Biodiversity and Ecosystem Resilience* (pp. 553-589). Singapore: Springer Nature Singapore.

5. Batool, A., Parveen, A., Nawaz, M., Razzaq, D., Mukhtar, M. and Mustafavi, N., 2025. Wetlands of Plains of Pakistan. *Wetlands of Tropical and Subtropical Asia and Africa: Biodiversity, Livelihoods and Conservation*, pp.67-83.
6. Qureshi, R., 2025. Plant Diversity and Useful Ecosystem Services of the Cholistan Desert, Pakistan. *Journal of Native and Alien Plant Studies*, (21), pp.1-21.
7. El-Saadony, M.T., Saad, A.M., Mohammed, D.M., Korma, S.A., Alshahrani, M.Y., Ahmed, A.E., Ibrahim, E.H., Salem, H.M., Alkafaas, S.S., Saif, A.M. and Elkafas, S.S., 2025. Medicinal plants: bioactive compounds, biological activities, combating multidrug-resistant microorganisms, and human health benefits-a comprehensive review. *Frontiers in immunology*, 16, p.1491777.
8. Elshafie, H.S., Camele, I. and Mohamed, A.A., 2023. A comprehensive review on the biological, agricultural and pharmaceutical properties of secondary metabolites based-plant origin. *International journal of molecular sciences*, 24(4), p.3266.
9. Sharma, A., Sharma, S., Kumar, A., Kumar, V. and Sharma, A.K., 2022. Plant secondary metabolites: An introduction of their chemistry and biological significance with physicochemical aspect. In *Plant secondary metabolites: physico-chemical properties and therapeutic applications* (pp. 1-45). Singapore: Springer Nature Singapore.
10. Khalid, A., Abdalgadir, E.A., Abdel Gadir, I.K., Abdalla, A.N., Homeida, H.E., Sultana, S., Rehman, Z.U., Hassani, R., Alqahtani, A.S. and Alhazmi, H.A., 2024. GC-MS Profiling and Therapeutic Potentials of *Prosopis juliflora* (Sw.) DC: Cytotoxic and Antimicrobial Insights. *Journal of Spectroscopy*, 2024(1), p.1121745.
11. Afaq, A., Aziz, S. and Butt, Z., 2024. Phytochemical Composition, Antioxidant and Antimicrobial Activities of *Prosopis juliflora* (Sw.) Dc. Grown in State of Azad Jammu and Kashmir, Pakistan: Activities of *Prosopis juliflora* (Sw.) in Azad Jammu Kashmir. *Pakistan Journal of Scientific & Industrial Research Series A: Physical Sciences*, 67(3), pp.205-219.
12. de Lemos, A.B.S., Chaves, G., Ribeiro, P.P.C. and da Silva Chaves Damasceno, K.S.F., 2023. *Prosopis juliflora*: nutritional value, bioactive activity, and potential application in human nutrition. *Journal of the Science of Food and Agriculture*, 103(12), pp.5659-5666.
13. Bibi, S., Bibi, A., Al-Ghouti, M.A. and Abu-Dieyeh, M.H., 2023. Allelopathic effects of the invasive *Prosopis juliflora* (Sw.) DC. on native plants: perspectives toward

- agrosystems. *Agronomy*, 13(2), p.590.
14. Abbas, A.M., Alomran, M.M., Alharbi, N.K. and Novak, S.J., 2023. Suppression of seedling survival and recruitment of the invasive tree *Prosopis juliflora* in Saudi Arabia through its own leaf litter: greenhouse and field assessments. *Plants*, 12(4), p.959.
 15. Miletić, Z., Mitrović, M., Sekulić, D., Jarić, S., Radulović, N., Jonjev, M. and Pavlović, P., 2026. Invasive Plants as Accumulators of Heavy Metals and Potentially Toxic Elements: A Review with Implications for Remediation. *Plants*, 15(7), p.1078.
 16. Paniagua-Zambrana, N.Y., Bussmann, R.W., Kikvidze, Z. and Khojimatov, O.K., 2025. *Morus alba* L. *Morus nigra* L. Moraceae. In *Ethnobotany of the Mountain Regions of Eastern Europe: Carpathians* (pp. 1787-1806). Cham: Springer Nature Switzerland.
 17. Fatima, M., Dar, M.A., Dhanavade, M.J., Abbas, S.Z., Bukhari, M.N., Arsalan, A., Liao, Y., Wan, J., Shah Syed Bukhari, J. and Ouyang, Z., 2024. Biosynthesis and pharmacological activities of the bioactive compounds of white mulberry (*Morus alba*): Current paradigms and future challenges. *Biology*, 13(7), p.506.
 18. Wang, Z.Y., Yan, K.L., Qin, Y.M., Zhang, N.C., Chen, X.C. and Chen, M., 2025. Effects of allelochemicals from plants on seed germination. *Seed Biology*, 4(1).
 19. Khade, O.S., Sruthi, K., Sonkar, R.M., Gade, P.S. and Bhatt, P., 2023. Plant secondary metabolites: Extraction, screening, analysis and their bioactivity. *International Journal of Herbal Medicine*, 11(2), pp.01-17.
 20. Singh, K. and Fatima, N., 2022. The efficiency of earthworms as a biomarker for environmental pollution. *International Journal of Biological Innovations*, 4(01), pp.104-112.
 21. Bibi, S., Bibi, A., Al-Ghouti, M.A. and Abu-Dieyeh, M.H., 2023. Allelopathic effects of the invasive *Prosopis juliflora* (Sw.) DC. on native plants: perspectives toward agrosystems. *Agronomy*, 13(2), p.590.
 22. Valiño, A., Pardo-Muras, M., Puig, C.G., López-Periago, J.E. and Pedrol, N., 2023. Biomass from allelopathic agroforestry and invasive plant species as soil amendments for weed control—A review. *Agronomy*, 13(12), p.2880.
 23. Guedes, L.M., de Oliveira, D.C., Sanhueza, C., Moreira, A.S. and Aguilera, N., 2024. Invasive *Teline monspessulana* and *Ulex europaeus* allelochemicals induce differential responses regarding the growth and physiological performance of two

- native Chilean tree species. *Acta Physiologiae Plantarum*, 46(3), p.32.
24. Ebana, K. and Okuno, K., 2022. Rice Allelopathy. In *Allelopathy* (pp. 253-265). CRC Press.
25. de Almeida, L., Gaspar, Y.M.D.S., Silva, A.A.R., Porcari, A.M., Lacerda, J.J.D.J. and Araújo, F.D.D.S., 2024. Allelopathic effect and putative herbicidal allelochemicals from *Jatropha gossypifolia* on the weed *Bidens bipinnata*. *Acta Physiologiae Plantarum*, 46(6), p.61.
26. Dang Xuan, T., Xuan Chien, N., Dang Khanh, T., Duc Viet, T. and Ngoc Minh, T.T., 2025. Advancements and challenges in allelopathy: A global perspective on agricultural practices. *Journal of Crop Health*, 77(5), p.151.
27. Vale, A.H., Cerato, B.M., Romero, J.H.C., González, Á.V., da Costa, L. and de Castro, W.A.C., 2026. Overview of Invasive Plants in Natural Areas of Brazil: A Systematic Review.
28. Xu, Y., Chen, X., Ding, L. and Kong, C.H., 2023. Allelopathy and allelochemicals in grasslands and forests. *Forests*, 14(3), p.562.
29. Ambhore, M.A., Bobade, P.N., Wakode, M.Y. and Khade, M.M., 2025. SEED DEVELOPMENT, DORMANCY AND GERMINATION. *A HANDBOOK OF*, p.112.
30. Baibout, M., Corcket, E., Kothari, S.L. and Fievet, V., 2022. Ecosystem services provided by *Prosopis cineraria* (L.) Druce in the drylands of Southern and Western Asia. *Botany Letters*, 169(1), pp.30-42.
31. Xin, X., Jiang, X., Thomas, A., Niu, B., Zhang, M., Xu, X., Zhang, R., Li, H. and Gui, Z., 2024. Studies on 1-deoxynojirimycin biosynthesis in mulberry (*Morus alba* L.) seeds through comparative transcriptomics. *Natural Product Research*, 38(15), pp.2585-2594.
32. de Almeida, L., Gaspar, Y.M.D.S., Silva, A.A.R., Porcari, A.M., Lacerda, J.J.D.J. and Araújo, F.D.D.S., 2024. Allelopathic effect and putative herbicidal allelochemicals from *Jatropha gossypifolia* on the weed *Bidens bipinnata*. *Acta Physiologiae Plantarum*, 46(6), p.61.
33. Chaves Lobón, N., González Félix, M. and Alias Gallego, J.C., 2023. Comparison of the allelopathic potential of nonnative and native species of Mediterranean ecosystems. *Plants*, 12(4), p.972.
34. Bradford, K.J. and Hilhorst, H.W., 2023. In Memoriam: J. Derek Bewley 1943–

2023. *Seed Science Research*, 33(1), pp.1-3.
35. Imarhiagbe, O., Okafor, A.C., Ikponmwosa, B.O. and Ogwu, M.C., 2023. Sustainable agricultural pest control strategies to boost food and socioecological security: the allelopathic strategy. In *One Health implications of agrochemicals and their sustainable alternatives* (pp. 637-657). Singapore: Springer Nature Singapore.
36. Edwards, C.A. and Arancon, N.Q., 2022. Earthworm ecology: communities. In *Biology and Ecology of Earthworms* (pp. 151-190). New York, NY: Springer US.
37. Nascimento-Gonçalves, E., Azevedo, T., Medeiros, C., Morais, M.C., Reis, A.R., Sousa, J.R., Oliveira, P.A., Coimbra, A.M. and Roboredo, M., 2026. Earthworm-Mediated Biocomposting and Basic Transformation Mechanisms in Organic Matter. In *Composting of Farm Residues by Nature-Based Solutions: A Potential Key Towards Sustainable Agricultural Practices* (pp. 59-88). Cham: Springer Nature Switzerland.
38. Alves, P.R.L., Bandeira, F.O. and Hennig, T.B., 2022. Ecological role of earthworms as bioindicators of soil health. *Life Sciences Research and Development*, 51.
39. Atarama-Castillo, S.A., Chanduví-García, R.G., Morocho-Romero, H., Peña-Castillo, R.A., Montero Salazar, A., Ruesta-López, M., Maza-Córdova, L., García-Zapata, M. and Morales-Pizarro, D.A., 2025. Characterization and scarification of Neltuma spp. Seeds from soil and trees. *Cuban Journal of Agricultural Science*, 59.
40. Baibout, M., Corcket, E., Kothari, S.L. and Fievet, V., 2022. Ecosystem services provided by *Prosopis cineraria* (L.) Druce in the drylands of Southern and Western Asia. *Botany Letters*, 169(1), pp.30-42.
41. Al-Khayri, J.M., Sahana, G.R., Nagella, P., Joseph, B.V., Alessa, F.M. and Al-Mssallem, M.Q., 2022. Flavonoids as potential anti-inflammatory molecules: A review. *Molecules*, 27(9), p.2901.
42. Roy, A., Khan, A., Ahmad, I., Alghamdi, S., Rajab, B.S., Babalghith, A.O., Alshahrani, M.Y., Islam, S. and Islam, M.R., 2022. Flavonoids a bioactive compound from medicinal plants and its therapeutic applications. *BioMed research international*, 2022(1), p.5445291.
43. Rajput, A., Sharma, R. and Bharti, R., 2022. Pharmacological activities and toxicities of alkaloids on human health. *Materials Today: Proceedings*, 48, pp.1407-1415.
44. Vasile, C., Tantar, G. and Creteanu, A., 2025. Recent Insights into the Research of (Bio) Active Additives for Advanced Polymer Materials. *Polymers*, 17(23), p.3139.

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

45. Olas, B., 2022. The antioxidant, anti-platelet and anti-coagulant properties of phenolic compounds, associated with modulation of hemostasis and cardiovascular disease, and their possible effect on COVID-19. *Nutrients*, 14(7), p.1390.
46. Rajabiyan, A., Bakhshi, D. and Hosseini, S.A., 2025. A methodological review of extraction, purification, and identification techniques for natural bioactive compounds. *Organic Process Research & Development*, 29(8), pp.1885-1915.
47. Batiha, G.E.S., Al-Snafi, A.E., Thuwaini, M.M., Teibo, J.O., Shaheen, H.M., Akomolafe, A.P., Teibo, T.K.A., Al-Kuraishy, H.M., Al-Garbeeb, A.I., Alexiou, A. and Papadakis, M., 2023. *Morus alba*: a comprehensive phytochemical and pharmacological review. *Naunyn-schmiedeberg's Archives of Pharmacology*, 396(7), pp.1399-1413.