OPEN ACCESS

Haya: The Saudi Journal of Life Sciences
Abbreviated Key Title: Haya Saudi J Life Sci
ISSN 2415-623X (Print) | ISSN 2415-6221 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Effect of *Euphorbia hirta* Leaf and Root Extracts on the Early Growth of Cucurbit Crops

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DOI: 10.36348/sjls.2024.v09i02.002 | **Received:** 23.11.2023 | **Accepted:** 04.02.2024 | **Published:** 19.02.2024

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Abstract

The research investigates the allelopathic influence of *Euphorbia hirta* extracts on the germination and seedling development of various cucurbit species, including Bottle gourd (Sp. A), Winter melon (Sp. B), Ridged gourd (Sp. C), Sponge gourd (Sp. D), Bitter gourd (Sp. E), Snake gourd (Sp. F), Muskmelon (Sp. G), and Pumpkin (Sp. H). The experimental design incorporated the use of both aqueous and methanol extracts of *E. hirta*, applied at different concentrations, with distilled water employed as the control. The findings reveal that the methanolic extract of *E. hirta* significantly impedes both the germination process and the subsequent growth of seedlings for all cucurbit species tested. For instance, at 12 days post-treatment, control groups exhibited high germination percentages (78%, 90.67%, 95.33% and 90% for Sp. A, Sp. C, Sp. D and Sp. E, respectively), which drastically declined with a 20% methanol extract concentration (23.33%, 18.33%, and 17.67% and 18.33% for the same species, respectively). Similarly, shoot and root length measurements indicated that higher concentrations of both extracts suppressed growth, with methanol extract showing a stronger inhibitory effect compared to the aqueous extract. Interestingly, Lower extract concentrations occasionally boosted shoot growth, revealing a hormetic effect. This two-fold response, notably in Pumpkin and Snake Gourd, illuminates the complexity of allelopathic interactions. The study suggests *E. hirta* extracts could serve as eco-friendly herbicides, urging further research to isolate their active components. This could lessen synthetic herbicide use, promoting sustainable agriculture and environmental protection.

Keywords: Allelopathy; *Euphorbia hirta*; Cucurbit crops; Seed germination; Root growth; Shoot growth.

INTRODUCTION

Allelopathy is a phenomenon in which one plant produces and releases allelochemicals that have inhibitory effects on the growth and development of other nearby plants [1] These allelochemicals, which can be secondary metabolites, play a significant role in shaping agricultural and biological systems, excluding animal systems [2-4]. Extensive research has been conducted on various weed species, revealing their capacity to produce allopathic substances [2-4]. These bioactive compounds, originating from different plant parts, are introduced into the environment through complex mechanisms such as volatilization, leaching, decomposition, and root exudation [8, 9]. These bioactive compounds exhibit a dichotomy in their classification, being segregated into primary and secondary metabolites, with this division being driven by their complicated chemical structures properties. These compounds span a spectrum that includes water-soluble organic acids, unadorned lactones, protracted long-chain fatty acids intermingled with polyacetylenes, intricate quinones, multifarious phenolic compounds, the extensive family of cinnamic acid and its intricate derivatives, the diversified group of coumarins, multifunctional flavonoids, multifarious tannins, diverse steroids, and the intricate realm of terpenoids [1, 10, 11]. This complexity centers their versatile nature and their role in the dynamic landscape of biological processes.

In recent times, there has been a growing interest in harnessing the potential of allelochemicals for weed management, as weed infestations significantly affect both the quantity and quality of crop yields (Rao, 2000). This stresses their relevance in

modern agricultural practices [11]. The allelopathic properties of several weed species have been studied and found to contain allelopathic substances. For instance, Ali *et al.*, [12] revealed that methanol extracts from twenty-two weed species inhibited the germination of various plants. Additionally, ten allelochemicals were identified in the methanol extracts of shoots, roots, and seeds of *Cephalaria syriaca* [11].

Understanding the mechanisms of action of crop allelochemicals has been challenging due to their complex composition, diverse origins, and synergistic effects. While some research has focused on compounds like sorgoleone, which can inhibit photosynthesis and respiration [5].Crops, especially modern cultivars, generally contain fewer allelochemicals than their wild counterparts or coexisting weeds, as they have been bred for yield rather than defense compounds [6]. However, conventional breeding and molecular-genetic technologies may offer opportunities to reintroduce beneficial genes, including those responsible for allelopathic compounds (Foley, 1999). Thoroughly understanding the mechanisms of crop-weed interference, reintroducing ancient beneficial practices, and developing crops with allelopathic properties for targeted weed management could prove advantageous [13].

Euphorbia hirta, also known as the asthma plant, is a pantropical weed with a distinctive hairy texture. It belongs to the Euphorbiaceae family, part of a diverse genus of over 1600 species [14]. Originating from tropical America, it has spread worldwide and displays allelopathic activity on various crops, including cereals, vegetables, oilseeds, and forage plants, due to its secondary metabolites, with leaves being the most toxic part. Bioactive compounds like alkaloids, terpenoids, flavonoids, and phenolic compounds contribute to this allopathic effect [15]. The interaction between *Euphorbia* species and crop plants is a crucial factor in agricultural productivity [16]. Studies have reported a reduction in seedling growth, delayed germination, and decreased chlorophyll and protein content in crops like maize and wheat when exposed to aqueous extracts of *E. hirta* and *E. hierosolymitana* at high concentrations [16]. However, the effects of *E. hirta* on cucurbitaceous crops have not been comprehensively studied. This research aims to explore the allelopathic impacts of *E. hirta* on various cucurbit crops, specifically focusing on the influence of leaf and root extracts on seed germination and subsequent plant growth.

MATERIALS AND METHODS

Sample Collection and Processing

In this research, the seed viability of eight distinct cucurbit crops, including Bottle gourd, Winter melon, Ridged gourd, Sponge gourd, Bitter gourd, Snake gourd, Muskmelon, and Pumpkin, was assessed using a float test. For each crop, 100 seeds were selected and immersed in a 200-ml beaker filled with distilled water for a duration of 5 to 10 minutes. The assessment of seed viability was based on the seeds' buoyancy: those that floated were considered non-viable, while those that sank were deemed viable. Concurrently, fresh leaves and roots of *E. hirta* (Figure 1) were collected from the botanical garden at the University of Chittagong. All experimental procedures were carried out at the Department of Botany, University of Chittagong, Chattogram, Bangladesh.

Figure 1: Separated Leaf (left) and root(right) of *E. hirta*

Extraction process

In the current experiment, 200 grams of fresh *E. hirta* leaves and roots were initially cleaned in distilled water to eliminate any impurities or contaminants. Afterward, they were left to air dry at room temperature (28-30°C) for 24 hours, avoiding direct sunlight exposure, until all moisture was removed. Subsequently, these dried samples were placed in an oven at 80°C for 48 hours. Following drying, the leaves and roots were ground into a fine powder using an electric grinder and passed through an 8.0 mm aperture size wire mesh net screen for uniformity. To ensure sterility, all glass jars and beakers were heat-sterilized by placing them in an oven at

180°C for approximately 15 minutes. The ground samples were then stored in airtight glass jars until further use.

For the extraction process, separate quantities of 5, 10, 15, and 20 grams of the leaf and root powders were soaked in 100 ml of distilled water and 80% methanol, respectively (Figure 2), for a duration of 24 hours at room temperature with continuous stirring. Afterward, the solutions were filtered through a 2 mm mesh sieve to eliminate any remaining undissolved large particles and then subjected to centrifugation at 3500 rpm for 15 minutes. The resulting extracts from both methods were stored in conical flasks and kept refrigerated at 4°C until further use in subsequent experiments.

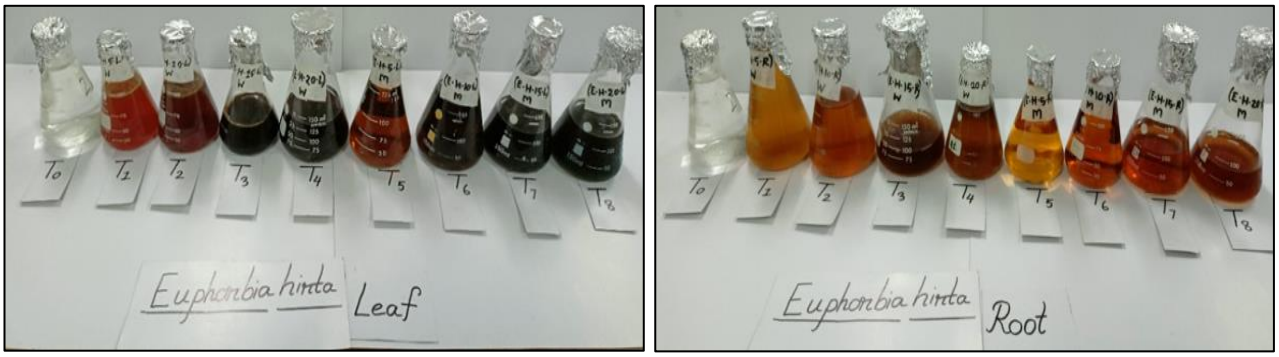

Figure 2: ***E. hirta leaf and root extract. T1-T4: Aqueous extract; T5-T6: Methanol extract; T0: Control***

Preparation for Bioassay:

In this study, Petri dishes, each with a 9 cm diameter, were precisely sterilized and prepared. Within each Petri dish, a Whatman No.1 filter paper was laid, and an appropriate soil medium was added. Ten seeds from various crop types were evenly sown in each dish, ensuring equal spacing. The experiment was conducted under controlled conditions at a constant room temperature of 23°C for 12 days to facilitate germination. Eight treatments (T1 to T8) were applied, including aqueous and methanolic extracts from *E. hirta* leaves and roots, along with a control group (T0) with seeds soaked in distilled water. Throughout the experiment, each dish received 5 ml of distilled water to maintain soil moisture. Seed germination success was determined by the emergence of a radicle exceeding 2 mm in length. After 12 days, the experiment was assessed for germinated seed count, root and shoot growth measurements, and the Final Germination Percentage (FGP) was calculated using the formula:

FGP = (Number of germinated seeds / Total number of seeds sown) × 100. This quantified the effectiveness of each treatment compared to the control group, providing valuable insights into the experiment's outcomes.

Statistical Analysis

Data analysis was performed thrice utilizing GraphPad Prism Data Editor (Version 8.4.3). Statistical evaluation involved the application of Dunnett's multiple comparison tests, encompassing both one-way and two-way analysis of variance (ANOVA). The results were presented in terms of the mean (average), standard deviation (SD) and p-values. Significance was determined at a significance threshold of $p < 0.05$.

RESULTS AND DISCUSSION

Germintion Percentage

Table 1 showed the variation of germination of cucurbit seeds was notably affected by the extracts of *E. hirta*. For instance, at 12 days post-treatment, control groups (distilled water) for species such as Bottle gourd (Sp. A), Winter melon (Sp. B), and Pumpkin (Sp. H) showed high germination percentages (78%, 68%, and 67.33% respectively). In contrast, a 20% methanol extract resulted in a drastic decline in germination, with values as low as 23.33% for Sp. A, 23.33% for Sp. B, and 25% for Sp. H. The methanolic extract consistently exhibited a stronger inhibitory effect on germination compared to the aqueous extract across all species. The combined results from Tables 4, 5, and 6 revealed that germination percentages were significantly reduced by the application of both aqueous and methanolic root extracts, with a more profound effect observed with methanol. For instance, at a 20% methanol concentration, germination rates dropped to as low as 13.33% in Bottle gourd (Sp. A) and 11% in Pumpkin (Sp. H), compared to their respective controls at over 80% (Table 4).

Shoot Length

At 12 days, shoot length was variably influenced by the treatment concentrations. The control groups maintained robust growth, with Winter melon (Sp. B) reaching a shoot length of 14.23 cm, while higher extract concentrations generally suppressed growth (Table 2). For example, at a 20% aqueous concentration, Bottle gourd (Sp. A) shoot lengths were measured at 5.7 cm, a reduction from the control.

However, certain species like Snake gourd (Sp. F) showed an anomalous increase in shoot length at lower extract concentrations, suggesting species-specific responses. In case of root extract, shoot elongation was also adversely affected, particularly by the methanol extract, with Bottle gourd (Sp. A), shoots measuring only 3.56 cm at a 5% methanol concentration, a stark contrast to the 10.1 cm length in the control. However, an interesting observation was made where certain treatments, such as a 20% aqueous extract, resulted in an increase in shoot length for some species, like 15.3 cm for Bottle gourd, which is higher than its control (Table 5).

Root Elongation

Root development followed a similar trend to shoot growth, with the control group exhibiting the longest roots presented in table 3. At 12 days, a 20% methanolic concentration resulted in shorter root lengths for most species, with Bottle gourd (Sp. A) roots measuring 8.3 cm, compared to 9 cm in the control. However, some species such as Sponge gourd (Sp. D) and Bitter gourd (Sp. E) displayed less sensitivity to the extracts in terms of root elongation (Table 3). For root extract, root elongation followed a similar pattern of inhibition, with the control group displaying the most significant growth across all species. For instance, the root length of Bottle gourd under control conditions was 8.16 cm, which decreased to 6.5 cm with a 5% aqueous extract and further to 9.2 cm with a 5% methanol extract, indicating a complex interaction between concentrations, extract type, and species (Table 6).

Comparison between Extracts and Species

The comparative analysis between aqueous and methanolic extracts indicates that the latter possesses a more pronounced inhibitory effect on both germination and growth. This effect is evident across all tested species, although the degree of susceptibility varies. For example, Pumpkin (Sp. H) maintained a germination percentage above 20% even at the highest concentration of methanol extract, whereas Bottle gourd (Sp. A) displayed a significant reduction to 13.33% (Table 1-6).

The differential response among species suggests a selective allopathic effect, which may be leveraged for targeted weed suppression. Species like Snake gourd (Sp. F) and Muskmelon (Sp. G), which exhibited less sensitivity to lower concentrations of extracts, might possess inherent resistance mechanisms. Conversely, Bottle gourd (Sp. A) and Winter melon (Sp. B), which showed considerable inhibition in germination and growth, could be more susceptible to the allelochemicals present in *Euphorbia hirta* (Table 1-6).

Table 1: Germination percent of eight cucurbit crops to distilled water (T_o) and different concentrations of aqueous & methanol leaf extracts of *Euphorbia hirta* at 12 days

Treatment	*Sp A*	*Sp B*	*Sp C*	*Sp D*	*Sp E*	*Sp F*	*Sp G*	*Sp H*
Control	78.00+2.00	68.00+3.46	90.67+4.04	95.33+5.03	90.00+5.00	96.67+5.77	100.00+0.00	67.33+3.06
AQE 5%	30.00+0.00b	23.33+5.77c	50.00+0.00b	65.00+5.00c	43.33+5.77ns	38.67+2.31c	75.00+5.00c	30.000.00b
AQE 10%	40.00+0.00b	30.00+0.00b	33.33+5.77c	40.00+0.00b	33.33+5.77ns	40.67+1.15b	75.005.00c	35.005.00ns
AQE 15%	40.00+0.00b	23.33+5.77c	26.67+5.77c	40.00+0.00b	33.33+5.77ns	44.00+5.29c	76.00+5.29c	29.00+1.73b
AQE 20%	45.00+5.00c	23.33+5.77c	23.33+5.77c	51.67+2.89c	36.00+5.29ns	28.00+2.00b	29.00+1.73a	25.00+5.00c
MTE 5%	29.00+1.73b	30.00+0.00b	23.33+5.77c	20.00+0.00b	17.33+4.62b	29.00+1.73b	44.00+5.29b	29.33+1.15c
MTE 10%	22.33+6.81b	18.33+2.89c	18.67+2.31b	19.00+1.73b	17.67+4.04c	37.33+3.06c	38.67+2.31b	27.33+3.06c
MTE 15%	25.67+4.04b	27.67+4.04c	19.33+1.15b	23.33+5.77b	18.00+3.46c	36.00+4.00c	45.67+5.13b	27.33+2.52c
MTE 20%	23.33+5.77b	25.33+5.03b	18.33+2.89b	17.67+2.08b	18.33+2.89c	45.00+4.36c	59.00+3.61b	29.33+1.15c

AQE: Aquous extract, and MTE: Methanol extract, a = p<0.001; b = p<0.01; **c** = p<0.05; and ns = not significant.
Sp A: Bottle gourd; Sp B: Winter melon; Sp C: Ridged gourd; Sp D: Sponge gourd; Sp E: Bitter gourd ; Sp F: Snake gourd; Sp G: Muskmelon and Sp H: Pumpkin.

Table 2: Shoot length of eight cucurbit crops to distilled water (T_o) and different concentrations of aqueous & methanol *Euphorbia hirta* leaf extracts at 12 days

Treatment	*Sp A*	*Sp B*	*Sp C*	*Sp D*	*Sp E*	*Sp F*	*Sp G*	*Sp H*
Control	10.16±0.12	14.23±0.16	13.16±0.12	11.6±0.08	22.5±0.08	17.16±0.12	12.6±0.08	11.16±0.12
AQE 5%	07.3±0.10b	6.4±0.08a	15.4±0.08b	07.6±0.08b	15.4±0.08c	08.9±0.08c	10.4±0.08c	05.9±0.08b
AQE 10%	08.4±0.10b	7.4±0.08a	7.9±0.08a	06.9±0.08b	06.9±0.08c	13.9±0.08b	8.7±0.08b	05.83±0.12b
AQE 15%	07.9±0.11b	10.4±0.08b	11.4±0.08b	08.9±0.08b	16.9±0.08c	14.4±0.08b	11.4±0.08ns	05.76±0.16b
AQE 20%	05.4±0.08a	10.4±0.08b	6.9±0.08a	13.4±0.08c	08.9±0.08c	08.9±0.08c	10.9±0.08	07.9±0.08a
MTE 5%	03.9±0.09a	11.9±0.08b	6.6±0.08a	05.1±0.08c	07.9±0.08c	06.9±0.08c	09.4±0.08b	06.6±0.08b
MTE 10%	03.9±0.08a	7.4±0.08a	4.1±0.08a	03.1±0.08c	15.4±0.08c	11.4±0.08b	05.9±0.08a	04.2±0.08c
MTE 15%	04.3±0.09a	6.4±0.08a	4.4±0.08a	04.5±0.08c	15.4±0.08c	09.4±0.08c	09.9±0.08a	03.2±0.08c
MTE 20%	04.2±0.09a	5.9±0.08a	6.9±0.08a	03.9±0.08c	08.4±0.08c	06.9±0.08c	09.9±0.08a	06.7±0.08b

AQE: Aquous extract, and MTE: Methanol extract, a = p<0.001; b = p<0.01; c = p<0.05; and ns = not significant.
Sp A: Bottle gourd; Sp B: Winter melon; Sp C: Ridged gourd; Sp D: Sponge gourd; Sp E: Bitter gourd ; Sp F: Snake gourd; Sp G: Muskmelon and Sp H: Pumpkin.

Table 3: Root elongation of receptor cucurbit crops to distilled water (T0) and different concentrations of aqueous & methanol *Euphorbia hirta* leaf extracts at 12 days

Treatment	*Sp A*	*Sp B*	*Sp C*	*Sp D*	*Sp E*	*Sp F*	*Sp G*	*Sp H*
Control	8.16±0.12	9.16±0.12	7.2±0.16	8.16±0.12	6.16±0.12	5.6±0.08	6.16±0.12	10.6±0.08
AQE 5%	7.4±0.08ns	7.9±0.08c	5.4±0.08c	7.3±0.08ns	5.9±0.08ns	6.9±0.08c	2.9±0.08b	5.4±0.08b
AQE 10%	6.9±0.08c	8.4±0.08ns	6.1±0.08ns	6.1±0.08c	6.9±0.08ns	4.9±0.08ns	2.9±0.08b	4.8±0.08b
AQE 15%	6.9±0.08c	7.9±0.08c	4.4±0.08c	5.9±0.08c	5.9±0.08ns	6.7±0.40ns	3.4±0.08b	6.4±0.08b
AQE 20%	6.4±0.08c	6.9±0.08c	5.4±0.08c	9.9±0.08c	4.9±0.08c	6.9±0.08ns	2.9±0.08b	6.9±0.08b
MTE 5%	6.5±0.08c	7.9±0.08c	9.4±0.08c	6.9±0.08c	10.4±0.08b	7.4±0.08c	2±0.08b	6.4±0.08b
MTE 10%	8.9±0.08ns	7.9±0.08c	4.9±0.08c	5.9±0.08c	5.9±0.08ns	5.4±0.08ns	1.5±0.08a	7.9±0.08b
MTE 15%	6.4±0.08c	7.9±0.08c	5.9±0.08ns	5.9±0.08c	7.9±0.08c	8.9±0.08b	1.16±0.12a	6.4±0.08b
MTE 20%	7.9±0.08ns	5.4±0.08b	6.9±0.08ns	5.4±0.08b	4.4±0.08c	4.9±0.08ns	2.1±0.08b	4.7±0.08b

AQE: Aquous extract, and MTE: Methanol extract, a = p<0.001; b = p<0.01; c = p<0.05; and ns = not significant.
Sp A: Bottle gourd; Sp B: Winter melon; Sp C: Ridged gourd; Sp D: Sponge gourd; Sp E: Bitter gourd ; Sp F: Snake gourd; Sp G: Muskmelon and Sp H: Pumpkin.

Table 4: Germination percent of eight cucurbit crops to distilled water (T0) and different concentrations of aqueous & methanol *Euphorbia hirta* root extracts (T_1-T_8) at 12 days

Treatment	*Sp A*	*Sp B*	*Sp C*	*Sp D*	*Sp E*	*Sp F*	*Sp G*	*Sp H*
Control	80.33+3.06	80.00+2.52	85.67+5.13	96.33+3.51	98.33+1.53	96.67+5.77	97.67+0.00	80.33+1.15
AQE 5%	30.00+0.00b	20.00+0.00b	30.00+10.00c	36.67+5.77b	43.33+5.77c	23.33+5.77c	97.33+2.08ns	45.33+5.03c
AQE 10%	33.33+5.77c	23.33+5.77c	30.00+10.00c	30.00+0.00b	33.33+5.77b	57.00+3.00c	76.00+2.52ns	30.00+0.00b
AQE 15%	33.33+5.77c	20.00+0.00b	43.33+5.77c	50.00+10.00c	33.33+5.77b	33.33+5.77b	36.33+4.00b	34.67+5.03b
AQE 20%	20.00+0.00b	20.00+0.00b	23.33=5.77c	30.00+0.00b	33.33+5.77b	26.67+5.77b	55.67+4.04c	25.00=5.00b
MTE 5%	23.33+5.77b	16.67+5.77b	23.33+5.77c	26.67+5.77a	20.00+10.00a	33.33+5.77b	42.67+3.79b	11.00+1.73a
MTE 10%	13.33+5.77b	23.33+5.77c	16.67+5.77b	20.00+0.00a	23.33+5.77a	33.33=5.77b	37.00+4.51b	10.00+0.00a
MTE 15%	16.67+6.77b	20.000.00b	13.33+11.55a	20.00+0.00a	16.67+5.77a	20.00+10.00c	67.33+2.65c	11.00+1.00a
MTE 20%	13.33+5.77b	23.33+5.77c	16.67+5.77a	26.67+5.77a	20.000+.00a	23.33+5.77c	97.67+2.52ns	11.33+2.31a

AQE: Aquous extract, and MTE: Methanol extract, a = p<0.001; b = p<0.01; c = p<0.05; and ns = not significant.
Sp A: Bottle gourd; Sp B: Winter melon; Sp C: Ridged gourd; Sp D: Sponge gourd; Sp E: Bitter gourd ; Sp F: Snake gourd; Sp G: Muskmelon and Sp H: Pumpkin.

Table 5: Shoot elongation of eight cucurbit crops to distilled water (T_o) and different concentrations of aqueous & methanol root extracts (T_1-T_8) of *Euphorbia hirta* at 12 days

Treatment	*Sp A*	*Sp B*	*Sp C*	*Sp D*	*Sp E*	*Sp F*	*Sp G*	*Sp H*
Control	10.1±0.08	14.1±0.08	13.16±0.12	11.5±0.08	22.6±0.08	17.16±0.12	12.5±0.08	11.66±0.47
AQE 5%	5.7±0.08a	12.03±0.04b	9±0.08b	4.5±0.35a	15.56±0.04b	13.5±0.08b	11.9±0.08ns	7.43±0.04c
AQE 10%	7.5±0.08c	7.4±0.08a	7±0.08a	3.5±0.08a	7.73±0.04a	6.1±0.08a	10±0.08b	6.93±0.04c
AQE 15%	8±0.08c	15.9±0.08c	8±0.08b	9.96±0.04b	15.3±0.08b	7.9±0.08a	10.9±0.08b	8.2±0.08c
AQE 20%	15.3±0.21b	12.5±0.08b	7.7±0.08a	10.9±0.08ns	11.9±0.08b	11.5±0.02b	5.9±0.08a	6.83±0.16c
MTE 5%	3.56±0.12a	2.53±0.04a	6.5±0.08a	14.3±0.21b	6.4±0.08a	10±0.08b	8.3±0.21a	5.9±0.08c
MTE 10%	3.46±0.12a	11.00±0b	4.3±0.08a	15.9±0.08b	8.4±0.08a	8.4±0.08a	10.4±0.08b	3.03±0.04b
MTE 15%	4.56±0.12a	4.2±0.08a	7.53±0.12a	8.9±0.08b	4.7±0.08a	10.9±0.08b	9.4±0.08b	6.1±0.08c
MTE 20%	4.4±0.08a	7.56±0.12b	15±0.08b	6.4±0.08a	4.9±0.08a	8.4±0.08a	12.4±0.08ns	3.06±0.09b

AQE: Aquous extract, and MTE: Methanol extract, a = p<0.001; b = p<0.01; c = p<0.05; and ns = not significant.
Sp A: Bottle gourd; Sp B: Winter melon; Sp C: Ridged gourd; Sp D: Sponge gourd; Sp E: Bitter gourd ; Sp F: Snake gourd; Sp G: Muskmelon and Sp H: Pumpkin.

Table 6: Root elongation of receptor cucurbit crops to distilled water (T_o) and different concentrations of aqueous & methanol *Euphorbia hirta* root extracts (T_1-T_8) at 12days

Treatment	*Sp A*	*Sp B*	*Sp C*	*Sp D*	*Sp E*	*Sp F*	*Sp G*	*Sp H*
Control	8.16±0.12	9.1±0.08	7.16±0.12	8.16±0.12	6.16±0.12	5.6±0.08	6.16±0.12	10.6±0.08
AQE 5%	6.9±0.08c	6.9±0.08b	3.9±0.08b	8.23±0.16ns	6.33±0.12ns	8.1±0.08b	2.5±0.08b	7.3±0.12b
AQE 10%	10.33±0.12c	8.9±0.08ns	3.9±0.08b	4.6±0.08b	7.33±0.12ns	6.9±0.08c	1.9±0.08b	4.9±0.08b
AQE 15%	6.4±0.08c	4.9±0.08b	8.3±0.08c	4.9±0.08b	4.9±0.08c	7.9±0.08b	1.4±0.08b	12.4±0.08c
AQE 20%	6.6±0.08c	7.4±0.08c	6.9±0.08ns	4.9±0.08b	6.9±0.08ns	5.4±0.08ns	2±0.08b	6.4±0.08b
MTE 5%	9.2±0.08ns	3.9±0.08b	7.33±0.12ns	5.9±0.08c	7.9±0.08c	5.9±0.08ns	2.9±0.08b	8.9±0.08c
MTE 10%	7.1±0.08ns	6.4±0.08b	6.6±0.08ns	8.9±0.08ns	4.9±0.08c	8.9±0.08b	4.9±0.08c	6.4±0.08b
MTE 15%	10.23±0.16c	5.9±0.08b	9.9±0.08b	5.9±0.08c	6.9±0.08ns	7.9±0.08b	1.9±0.08b	4.9±0.08b
MTE 20%	8.3±0.21ns	7.33±0.12c	5.4±0.08c	5.9±0.08c	4.9±0.08c	6.9±0.08c	3.36±0.12c	6.7±0.08b

AQE: Aquous extract, and MTE: Methanol extract, a = p<0.001; b = p<0.01; c = p<0.05; and ns = not significant.
Sp A: Bottle gourd; Sp B: Winter melon; Sp C: Ridged gourd; Sp D: Sponge gourd; Sp E: Bitter gourd ; Sp F: Snake gourd; Sp G: Muskmelon and Sp H: Pumpkin.

DISCUSSION

Weeds are the third largest threat to biodiversity, behind anthropogenic destruction and disturbance of native vegetation and anthropogenic modification and degradation of abiotic variables, according to a comparison of weed impacts with the major threat hierarchy categories [17]. Allopathic weeds have a negative influence on crops and cause large losses on plantations. The substances that seed plants emit restrict not just the growth and development of subsequent plants but also those that grow alongside them [18]. The observed inhibitory effects of *Euphorbia hirta* leaf extracts on the germination and growth of cucurbit crops highlight the plant's potential allelopathic properties in our study. Methanol extracts displayed a stronger suppression compared to aqueous extracts, which could be attributed to the better solubility of allelochemicals in methanol, suggesting that these compounds may be more active or present in higher concentrations when extracted with an organic solvent. The similar findings was found by Jabeen & Ahmad [19] who observed that highest concentration delayed seedling growth of maize and wheat compared to lowest one. It means this extract could be used as a growth inhibitor or stimulator for crops depending upon the dose of application [20].

The differential sensitivity among species to the extracts is noteworthy. While all species exhibited reduced germination rates and growth in response to increasing concentrations of extracts [20], species such as Pumpkin (Sp. H) and Snake gourd (Sp. F) showed a relatively higher tolerance. This variation could be due to inherent genetic differences that confer resistance to the allelopathic compounds or perhaps differential absorption rates of these compounds. For example, the thick seed coat of Pumpkin might impede the penetration of allelochemicals, thus reducing their inhibitory impact [21],

Furthermore, the fact that some species showed increased shoot length at lower concentrations of the extracts, notably Snake gourd, suggests a hormetic response. Hormesis is characterized by a stimulation of growth at low doses of a stressor, followed by inhibition at higher doses. This biphasic response is a common biological reaction to a wide range of environmental stressors [22] and indicates that at low concentrations, *Euphorbia hirta* extracts could have a stimulatory effect on certain cucurbit crops.

The pronounced inhibitory effect on root elongation, especially in Bottle gourd and Winter melon, could have significant implications for plant establishment and nutrient uptake, potentially affecting overall plant health and yield. Roots are crucial for water and nutrient absorption, and their development is a vital component of plant growth. Thus, the suppressive effect on root elongation could translate to a broader ecological impact if *Euphorbia hirta* were present in agricultural settings [23].

This study's findings align with previous research indicating that plant extracts can have allopathic effects, which could be exploited for weed management in agricultural systems. However, the potential for non-target effects on desired crop species must be considered. The use of *Euphorbia hirta* extracts as a natural herbicide could reduce reliance on synthetic chemicals, but the specificity of the effect and the potential for crop damage must be thoroughly investigated [24, 25].

In conclusion, the research provides valuable insights into the allelopathic interactions between *Euphorbia hirta* and cucurbit crops, revealing that both aqueous and methanolic extracts of *E. hirta* leaves and roots can inhibit the germination and early growth of cucurbit crops, with the methanolic extract showing a more potent effect. The variations in response among different cucurbit plants emphasize the complexity of allelopathic interactions and the potential for customized agricultural applications without focusing on particular species. These findings could be instrumental in developing organic herbicides and understanding crop-herb interactions. Further research is necessary to isolate the active compounds and elucidate their mechanisms of action on different plant species.

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