SSR Journal of Engineering and Technology (SSRJET)

OPEN ACCESS

Volume 2, Issue 3, 2025 Journal homepage: https://ssrpublisher.com/ssrjet/ ISSN: 3049-0383
Email: office.ssrpublisher@gmail.com

Germination and Growth Morphological Response of Cucumber (Cucumis Sativus L.) to Mercury (Hg) Toxicity

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Received: *20.06.2025* | ***Accepted:*** *20.07.2025* | ***Published:*** *07.08.2025*

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DOI: *10.5281/zenodo.16762541*

Abstract **Case Studies**

Mercury (Hg) contamination in agricultural soils poses a serious threat to plant development. This study evaluated the impact of Hg toxicity on the germination and growth morphology of cucumber (Cucumis sativus L.) at concentrations of 100, 200, and 400 ppm. Results indicated a dose-dependent reduction in germination percentage, decreasing from 80.5% at 100 ppm to 59.1% at 400 ppm, compared to 92.5% in the control. Growth morphological traits, including leaf area, shoot length, and root length, declined progressively with increasing Hg concentrations, with reductions of 33%, 36%, and 45%, respectively, at 400 ppm. Biomass accumulation was significantly affected, as fresh and dry weights decreased by 21% and 35%, respectively. Furthermore, membrane rupture increased from 19.5% at 100 ppm to 40.9% at 400 ppm, indicating severe oxidative stress and cellular damage. These findings highlight the detrimental effects of Hg on seedling establishment and early growth, emphasizing the need for soil decontamination strategies in Hg-polluted environments.

Keywords: Mercury toxicity, Cucumis sativus, germination, morphological traits, oxidative stress, heavy metal pollution.

Citation: Kafin Hausa, S. S., Muktar, U., Abdulrahman, K., Baiwa, F. I., Ahmad, S., Muhammad, M., Darma, S. A., Miko, H., Baiwa, K. I., & Abdullahi, M. (2025). Germination and growth morphological response of cucumber (Cucumis sativus L.) to mercury (Hg) toxicity. *SSR Journal of Engineering and Technology (SSRJET)*, 2(3). [19-21]

1. INTRODUCTION

Heavy metal contamination of agricultural soils is a growing environmental concern worldwide. Among these contaminants, mercury (Hg) is particularly toxic due to its high mobility and bioaccumulation potential (Alloway, 2013; Zhang *et al.*, 2020). Mercury can enter agricultural systems through industrial effluents, atmospheric deposition, and agrochemical use, causing adverse effects on soil health and crop productivity (Kabata-Pendias and Mukherjee, 2007).

Cucumis sativus L. (cucumber) is widely cultivated for its nutritional value but is sensitive to abiotic stress, including heavy metal exposure. Previous research has shown that mercury inhibits enzymatic activity, disrupts photosynthesis, and causes genotoxicity in plants (Gupta *et al.*, 2014; Singh *et al.*, 2017). Moreover, studies by Sharma and Dubey (2005), Choudhury and Panda (2005), and Yadav (2010) demonstrated how Hg interferes with vital physiological pathways.

This study investigates how varying mercury concentrations affect seed germination and the early morphological development of cucumber, providing insight into the crop's tolerance and response mechanisms under metal stress.

2. MATERIALS AND METHODS

2.1 Experimental Design

The experiment was conducted under controlled greenhouse conditions in Department of Biology, Khadija University Majia, Taura in Jigawa State. Cucumber seeds were planted in sterilized sandy loam soil treated with $HgCl_2$ to create 100, 200, and 400 ppm Hg concentrations. A control group was maintained without Hg. Each treatment had three replicates.

2.2 Germination Assessment

Ten days after sowing, seeds with radicle emergence ≥2 mm were counted. Germination percentage was calculated.

2.3 Morphological Measurements

After 21 days, shoot length, root length, leaf area (via ImageJ), and biomass (fresh and dry weight) were recorded. Dry weight was taken after oven-drying at 70°C for 48 hours as per method of Yadav (2010).

2.4 Membrane Damage Estimation

Membrane integrity was assessed using electrolyte leakage according to method of Choudhury and Panda (2005): samples were incubated in distilled water, and conductivity was measured pre- and post-autoclaving.

2.5 Statistical Analysis

Data were analyzed via one-way ANOVA and Tukey's HSD test ($p < 0.05$) using SPSS v25. Different letters indicate significant differences.

3. RESULTS

Table 1 shows the germination percentage of cucumber seeds across treatments. Tables 2 and 3 present morphological data and membrane damage.

Treatment	**Germination (%) ± SD**	**Superscript**
Control	92.5 ± 2.1	a
100 ppm Hg	80.5 ± 1.8	b
200 ppm Hg	70.3 ± 2.0	c
400 ppm Hg	59.1 ± 2.5	d

Table 2: Morphological Parameters

Parameter	**Control**	**100 ppm Hg**	**200 ppm Hg**	**400 ppm Hg**	**Superscripts**
Shoot Length (cm)	15.4 ± 0.5	12.6 ± 0.4	10.9 ± 0.3	9.8 ± 0.2	a–d
Root Length (cm)	12.1 ± 0.3	9.4 ± 0.4	7.8 ± 0.3	6.6 ± 0.3	a–d
Leaf Area (cm^2)	24.6 ± 1.2	20.9 ± 1.1	18.2 ± 1.0	16.5 ± 0.9	a–d
Fresh Weight (g)	4.8 ± 0.2	4.2 ± 0.2	4.0 ± 0.1	3.8 ± 0.2	a–c
Dry Weight (g)	2.0 ± 0.1	1.6 ± 0.1	1.4 ± 0.1	1.3 ± 0.1	a–c

Table 3: Membrane Rupture (%)

Treatment	**Membrane Rupture (%) ± SD**	**Superscript**
Control	10.3 ± 0.8	a
100 ppm Hg	19.5 ± 1.1	b
200 ppm Hg	30.2 ± 1.4	c
400 ppm Hg	40.9 ± 1.6	d

4. DISCUSSION

The observed reduction in germination rate under mercury stress supports findings by Singh *et al*. (2017) and Liu *et al*. (2011), who demonstrated the inhibitory effects of Hg on seed metabolic activation and enzyme function. Mercury impairs seed respiration, water uptake, and mitochondrial activity, all of which are vital for germination (Khan *et al*., 2006).

Shoot and root length reductions were pronounced and consistent with reports by Patra *et al*. (2004) and Gill *et al*. (2012), who attributed growth retardation to Hg-induced hormonal imbalance and interference with cell division. Root systems are more susceptible due to their direct contact with contaminated soil (Mishra *et al*., 2006).

Reduced leaf area under Hg exposure aligns with the studies of Panda and Choudhury (2005), who noted suppressed chlorophyll biosynthesis and photosynthetic rates under mercury stress. According to Rascio and Navari-Izzo (2011), heavy metals reduce stomatal conductance and CO_2 assimilation, thus impairing leaf development.

Declining biomass accumulation has been linked to oxidative stress and hindered photosynthate allocation (Singh *et al*., 2016; Sharma *et al*., 2008). Hg-induced reactive oxygen species (ROS) production damages proteins and nucleic acids, as highlighted by Yadav (2010) and Gupta *et al*. (2014).

Increased membrane damage further confirms oxidative stress, as described by Verma and Dubey (2003), where lipid peroxidation caused membrane instability. High electrolyte leakage is a direct indicator of cellular injury, as supported by Saxena *et al*. (2005).

Overall, the results strongly affirm that Hg exposure disrupts multiple physiological processes in C. sativus, limiting its viability and productivity.

5. CONCLUSION

This study confirms that mercury contamination adversely affects cucumber germination and morphological development in a dose-dependent manner. The observed physiological disturbances and cellular damage stress the importance of preventing and remediating Hg pollution in agricultural soils to ensure food safety and crop productivity.

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