

Effects of mercury on germination, growth and ultrastructural deformation in *Vigna radiata* (L) Wilczek

Ranjan Kumar Pradhan

Gandhi Institute of Engineering and Technology University: GIET University

Durga Prasad Pattanaik

Gandhi Institute of Engineering and Technology University: GIET University

Goutam Sabat

Khallikote College: Khallikote Unitary University

Sunita Nayak

Institute of Life Sciences

Manoja Das

manojadas@giet.edu

Gandhi Institute of Engineering and Technology University: GIET University <https://orcid.org/0000-0002-1571-3295>

Research Article

Keywords: phytotoxicity, Mercury pollution, Anatomical deformation, *Vigna radiata*

Posted Date: July 28th, 2025

DOI: <https://doi.org/10.21203/rs.3.rs-7033917/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Mercury is one of the heavy metals that can cause harm to crops, ecosystems, and human health. *Vigna radiata* (L) Wilczek plants were cultivated hydroponically in solutions containing varying doses of mercury (Hg), ranging from 1 to 5 ppm, as HgCl_2 . The negative impact of mercury on seed germination was observed at concentrations of 2 ppm and 5 ppm, with 50% inhibition noted. Both catalase and peroxidase, two of the enzymes under study, were found to raise activity to 3 ppm in treated plants before declining. In the plants treated with mercury, the activity of other enzymes continuously decreased with an increase in mercury concentration. The transverse sections of the treated plant were subjected to energy dispersive X-ray analysis (EDX), which revealed that mercury was deposited throughout the plant's tissues of both root and stem. All treated plants showed a decrease in morphological characteristics such as root and shoot length as compared to the control. The biochemical characteristics of the treated plants showed a similar pattern. Mercury was deposited in the roots and stems of the treated plants, causing anatomical deformation, as seen in the scanning electron micrograph of the experimental plants. In plants exposed to mercury at concentrations of 1 ppm or higher, conducting tissues in both the roots and the stems shrank, and in plants exposed to mercury at concentrations of 3 ppm or higher, tissue damage was documented. The study demonstrated that mercury has a cytotoxic impact on the well-known legume *V. radiata* and that plants growing in areas contaminated by mercury can be correlated with the investigation.

Introduction

There are two types of mercury that are found in nature, such as elemental mercury and organic mercury complexes (Pavithra et al. 2022). Mercury is indestructible and non-biodegradable; it persists in the soil for a long period after it is introduced, potentially jeopardising the environment and ecosystems. Mercury is poisonous to both plants and animals and is not necessary for any biological processes (Albatrni et al. 2020). Mercury can easily be absorbed and stored by plants from the soil, water, and environment. Once the element has been absorbed, it can simply be carried out and retained in several plant components, including roots, stems, leaves, and fruits (Aliprandini et al. 2020). As a result, the growth, development, and general health of plants are negatively impacted by mercury. Even though mercury is poisonous to plants, several plant species have evolved defences against it. Some plants can sequester mercury in specific storage compartments or transform it into less harmful forms (Bowman et al. 2019). The olden pulse crops *Vigna* species are native to Asia and Africa. The mung bean (*Vigna radiata*) is a legume plant belonging to the family Fabaceae of peas, grown for its edible seeds and early sprouts (Ganesan and Xu 2017). It is a significant species of legume that is grown and eaten extensively around the world. Due to its short growth cycle, drought resistance, and high nutritional content, this crop may be grown in a variety of agroecological zones (Lee et al. 2011). Earlier investigations have demonstrated that plants can absorb mercury from the culture media, and the findings suggest that plants can either accumulate or volatilize mercury (Kumar et al. 2013). Some plants are extremely poisonous to mercury. There aren't many studies detailing how it affects plants, especially when it comes to ultrastructural deformation of

the plant tissue. Barley experiments showed that Hg sprayed at 5 mg/kg soil decreased the shoot height by 2.5% and the germination of seeds by 20% as reported by Fayez and Bazaid (2013). The antagonistic effect of mercury on the biotype of *Vigna* species grown in the area, however, has not been documented. The current study was conducted in hydroponic systems to ascertain the absorption of mercury and its impact on the morphological and biochemical characteristics of *Vigna radiata* being cultivated by the local tribal people. Scanning electron microscopy (SEM) was used to examine the ultrastructural anomalies caused by the toxic effect of mercury in the treated *Vigna* plants. The study sought to determine the harmful effects of mercury chloride on morphological and biochemical characteristics, ultrastructural deformation, and germination toxicity in *Vigna radiata*.

Materials and methods

a) Effect of Hg on seed germination and plant growth: Viable seeds of green gram, *Vigna radiata* (L), that were cultivated by the local tribal people at a location where there had been no prior reports of metal pollution were collected for the study. Seeds' biological properties were confirmed at the agricultural office located near the university. Seeds were surface sterilised using sodium hypochlorite solution before being utilised for germination. Ten seeds were placed equally apart from each other on the cotton net of the Petri dish, where variable concentrations of test chemical, HgCl_2 solution, ranging from 1 ppm to 10 ppm, were added to the individual containers. The test containers were put in a seed germinator with 90% relative humidity and a temperature of 20°C under a 16/8-hour light/dark cycle and 52 mol/(ms) of radiation for five days. The appearance of plumules and radicals from the seed was assumed to be a sign of germination. Three repetitions on average were used to record the experimental results. Seedlings were cultivated for a week in a hydroponic system with solely Hoagland nutrient solution, then exposed to HgCl_2 solution at concentrations ranging from 1 ppm to 5 ppm. In the control container, the seedlings were grown with Hoagland solution only. Three duplicates of each treatment were administered to all sets of ten plants.

b) Examination of morphological characters, biochemical analysis: All plants were regarded as sample units at harvest. The plants were exposed to 52 mol/(ms) of radiation while growing in the treatment solution for a week, utilising a 16/8-hour light/dark cycle. The seedlings were collected, their roots submerged in 0.1M HNO_3 for a minute, and then cleaned with deionised water (DI). The plants were then separated into roots and stems, before being oven-dried for 72 hours at 70°C. Conventional methods were used to measure the root and shoot lengths of the plants using a scale. The pheophytin, carotenoids, and chlorophyll levels of the plant samples were assessed following the earlier proposed process (Pérez-Gálvez et al.2020). In a similar manner, the Lowry method and the Anthrone method were used to quantify the protein and soluble sugar amounts found in the plant samples (Kurzyna-Szklarek et al. 2022).

c) Study of enzymatic activity: There is no nutritional need for mercury in plants and animals. Biological systems exposed to very low quantities of mercury can quickly become seriously hazardous due to oxidative stress caused by the element, which damages DNA and cell membranes, causes lipid

peroxidation and inhibits enzymatic activity. In all enzymatic activity analyses of the plant samples, tissue homogenization is usually carried out in a phosphate or Tris buffer (pH 6.8–8.0 on ice) and then centrifuged, and the presence of enzymes is determined in the supernatant. The modified earlier methods were used to spectrophotometrically evaluate the activity of the plant tissue's catalase and peroxidase enzymes. Measurements of polyphenol oxidase (PPO) and superoxide dismutase (SOD) were made by following the method as catechol, a phenolic substrate for PPO, and NBT photoreduction inhibition as a substrate for SOD, using a spectrophotometer following the standard procedure (Weydert and Cullen 2009).

d) FTIR analysis: Fourier transform infrared spectroscopy (FTIR) assists in identifying certain functional groups in the chemicals found in roots or stems, such as hydroxyl, carboxyl, or amide groups. Carbohydrates, proteins, lipids, and other macromolecules can be detected by using FTIR (Gong et al. 2024). The root samples of *Vigna* were baked for 4 h at 40–60°C until they were totally dry. Small amounts of root powder were applied directly onto the crystal surface, and the wavenumber range of the instrument and resolution were adjusted to 4000–400 cm⁻¹ and 4 cm⁻¹, respectively. The root sample was then analyzed carefully and the spectra were recorded.

e) Ultrastructural study of plant roots and stem: A common method for examining the morphology and physiology of plant components is scanning electron microscopy (SEM). The control and treated plants were separated into roots and stems, frozen in liquid nitrogen, and then broken up into tiny fragments using a blunt knife. The pieces were vacuum-dried and freeze-dried for a whole night at 30°C. Double-sided carbon tape was used to attach the samples on aluminium stubs. With scanning electron microscope operating in low vacuum mode was used to make the SEM observations in backscattered electron imaging.

f) Statistical analysis: The standard error of the arithmetic means is used for all data. Sample means were compared using the multiple comparison Tukey test, and the data was analyzed using one-way analysis of variance (ANOVA). SPSS program version 12.0 was used to conduct statistical analyses.

Results and Discussion

Seed germination is the biological process through which a seed initiates sprouting and develops into a new plant under suitable environmental conditions (Wang et al. 2024). *Vigna radiata* seeds were subjected to germination in varying concentrations of mercuric chloride ranging from 1 ppm to 10 ppm under controlled laboratory conditions, and the corresponding results are illustrated in Fig. 1. The germination of *Vigna radiata* seeds exhibited a differential response to mercuric chloride treatment when compared to the untreated control.

A significant reduction in germination percentage under higher mercury concentrations indicates that excessive mercury exposure may inhibit phytochemicals present in the seeds. Previous studies have reported that inorganic mercury can exert toxic effects on aquatic plants at concentrations as low as 5 µg·l⁻¹ in culture media (Boening 2000). A 100% germination of seeds was recorded in the control, where

seeds were grown solely in Hoagland's solution. The data clearly show a negative correlation between mercury concentration and seed germination, with increasing mercury levels leading to a progressive decline in germination rates. Since 50% of the seeds germinated at such concentration, the LC50 was 5 ppm. The LC 100, where 10 PPM of mercury chloride reduced seed germination. Because of the dose-dependent nature of mercury's harmful effects, germination is more severely inhibited at higher doses (Rice et al. 2014). Both the early germination process and the following development of the seedlings exhibit this inhibition. According to a previous study, plants are hyperaccumulators of mercury from the soil or air, which stunts their development and alters how their metabolic pathways are regulated (Memon et al. 2021). Figure 2 illustrates the impact of varying concentrations of mercury chloride on the morphological traits of *Vigna radiata* seedlings. For plants to explore for water and minerals, they must have longer shoot and root.

The seedling demonstrated a steady reduction in development as the mercury chloride concentration increased from 1 ppm to 5 ppm. The impact of mercury chloride on *Vigna radiata* morphological characteristics is shown in Fig. 3. Seven-day-old green gram seedlings treated with varying concentrations of mercury chloride showed variations in morphological components such as root and shoot length (in cm).

The length of the roots and shoots gradually decreased as the amount of mercury chloride increased. The plants treated with 5 ppm of mercury chloride showed the greatest drop in percentages of shoot length and root length, at 75% and 94.38%, respectively. With regard to various concentrations of mercury chloride over control, a decrease in the fresh weight and dry weight of roots and shoots was noted. At 5 ppm, the fresh weight of roots and shoots decreased by a maximum of 82.14% and 65.38%, respectively. Further, at the concentration, the highest reduction in dry weight of the root and shoot of *Vigna* was 93.30% and 33.33%, respectively. The metric used to quantify seedling growth is biomass. The toxicity of mercury chloride is the cause of the seedling's decreased biomass. It has been reported earlier that, at a particular range of mercury chloride solution treatment, the green gram seedlings survived, and the same trend was observed in the investigation. The impact of mercury chloride on the biochemical parameters of *Vigna radiata* is depicted in Fig. 4, illustrating how mercury chloride affects metabolic parameters of *Vigna radiata*. The amount of total chlorophyll, carotenoid, and phaeophytin in seedling shoots that were 7 days old and treated with varying concentrations of mercury chloride (1 ppm to 5 ppm).

As the concentration of mercury chloride increased from 1 ppm to 5 ppm, a notable decrease in the total chlorophyll, carotenoid, and phaeophytin content of *Vigna radiata* was noted. The total decrease percentages for carotenoid, phaeophytin, and total chlorophyll were 79.54%, 87.17%, and 68.726%, respectively. Additionally, the seedlings treated with different doses of mercury chloride showed notable variations in the amount of biochemicals, including sugar and protein. As the quantity of mercury chloride increased above the control value, the sugar content of *Vigna radiata* roots and shoots significantly decreased. However, the protein content of the root and shoots progressively rose until the concentration of mercury chloride reached 3 ppm, after which it began to decline. The impact of mercury

chloride on the enzymatic activity of *Vigna radiata* plants cultivated for seven days is shown in Figure 5. Up until the plants treated with 3 ppm of mercury chloride, the two investigated enzymes, catalase, and peroxidase, demonstrated increased activity; beyond that, they were found to be diminished.

Catalase activity may rise in response to elevated mercury levels as a defense against oxidative stress. The enzyme is also essential for shielding cells from oxidative damage (Nandi et al. 2019). In response to elevated oxidative stress brought on by mercury exposure, cells increase the activity of antioxidant enzymes such as glutathione peroxidase and superoxide dismutase as well as catalase. Similarly, as part of the plant's defensive system against oxidative stress, elevated mercury levels might cause an increase in peroxidase activity. As antioxidant enzymes, peroxidases are essential for scavenging these ROS, and their activity rises in response to mercury's oxidative damage (Li et al. 2024). Other investigated enzymes showed a tendency of decreased enzymatic activity as mercury treatment increased. The main reason why higher mercury levels reduce enzymatic activity is that mercury binds to and changes the structure of enzymes, especially at their active sites, making it more difficult for them to catalyze processes as per Yu and Barkay (2022). This binding may be irreversible, rendering the enzyme inactive for good. Mercury may induce the enzyme to undergo a conformational shift, which would disrupt its active site and make it impossible for the enzyme to bind to its substrate (Elbaz et al. 2010). FTIR spectroscopy is a non-destructive method that can detect and measure the existence of various functional groups (such as O-H, C = O, and C-H) in a material. Figure 6 shows the results of an FTIR study of the roots of a *Vigna radiata* plant that was grown *in vitro* and exposed to mercury chloride, from 1 ppm to 5 ppm for seven days. The molecular structure of the root tissue of *V. radiata* had been altered in seven days of mercury chloride treatment, according to FTIR analysis. It demonstrated changes and shifts in the vibrational frequencies of different chemical interactions, especially those connected to proteins, lipids, and other biomolecules, as a result of mercury interfering with biological functions (Khan et al. 2018).

These alterations can be correlated to how mercury is and how it affects the biochemistry of the plant. It is established that mercury chloride is a hazardous heavy metal that can interfere with a number of plant cellular functions, such as photosynthesis, enzyme activity, and nutrient absorption (Fatima et al. 2025). Scanning electron microscopy micrographs of *V. radiata* roots treated with mercury for 7 days are displayed in Fig. 7. The effects of mercury on *V. radiata* have shown that these effects are likely to be correlated with decreased plant growth and vigor. Depending on the mercury content, scanning electron microscopy (SEM) micrographs of *V. radiata* roots exhibit a variety of effects.

Damage at lower concentrations was minor, including a little alteration to the surface structure of the root. However, higher concentrations of mercury cause serious harm, such as damaged or collapsed root hairs, changes in the structure of vascular tissue, and even necrosis or cell death. The roots of the control plants have a smooth, undamaged surface with distinct epidermal cells and vascular tissue, as shown in SEM pictures. The energy dispersive spectroscopy associated with SEM showed the presence of mercury in the root tissue. The maximum and minimum Hg peaks were observed at 3.12k and 0.85k,

respectively. Scanning electron microscopy micrographs of *V. radiata* stems treated with mercury for seven days are shown in Fig. 8.

The SEM photographs enable us to examine the plant tissue's micromorphology, revealing information on surface characteristics, cell structure, and any changes brought on by mercury contamination. SEM images of the stem revealed structural changes at the cellular and tissue levels as well as potential damage from mercury exposure, such as the contraction of the plant's conduction tissue. Complete interior tissue destruction was seen in plants treated with greater concentrations of mercury, such as those treated with more than 4 ppm. SEM-associated energy dispersive spectroscopy revealed that mercury was deposited in the stem tissue. Mercury-treated plant tissues exhibited severe ultrastructural damage, including ruptured cell walls, plasmolysis, deformed stomata, and irregular surface morphology, according to SEM analysis. These anomalies point to cellular stress and compromised structural integrity, indicating that mercury toxicity has a significant impact on tissue organization, which may hinder physiological processes and plant development as a whole (Gusev and Zotova 2019).

Conclusion

This study illustrates the detrimental effects of mercury (Hg) toxic on the germination, growth, and ultrastructural integrity of *Vigna radiata* (L.) Wilczek, a major leguminous crop. The physiological and biochemical processes required for a plant's healthy growth are significantly hampered by the heavy metal mercury. Our findings confirm that exposure to mercuric chloride (HgCl_2) causes a marked reduction in the germination percentage, a delayed onset of germination, and decreased vigor of seedlings, even at relatively low concentrations. The decrease in germinability can be attributed to oxidative stress, mercury ion-induced enzyme inhibition, and cellular toxicity. Growth metrics like fresh and dry biomass, root and shoot length, all dramatically declined as mercury levels rose. Root systems were more negatively affected than shoots, indicating that roots may absorb and store more mercury as the first site of interaction with the metal in the growth media, leading to direct cytotoxic effects. There were notable decreases in the concentrations of chlorophyll a, chlorophyll b, and total chlorophyll, which may indicate damage to the photosynthetic apparatus and a disruption. It has been demonstrated that photosynthetic pigments are physiologically disrupted by mercury stress. The substantial drop in chlorophyll a, chlorophyll b, and total chlorophyll concentrations indicated damage to the photosynthetic apparatus and a disruption in the efficiency of light-harvesting. Important mercury-induced cellular abnormalities were found using scanning electron microscopy (SEM) for ultrastructural studies. Mercury poisoning in leaf tissues resulted in reactions such as the compartmentalization or sequestration of mercury ions, which included the loss of grana stacks, thylakoid membrane enlargement, chloroplast disarray, and as a whole shrinkage of the cell. This study emphasizes the need to monitor and control mercury pollution in agricultural soils, particularly in areas near industrial discharge sites. Because of its vulnerability to mercury stress, *Vigna radiata* may also be a bioindicator of environmental toxicity. Future research should focus on examining phytoremediation techniques, antioxidant function, and mercury detoxification processes to lessen crop plant stress brought on by heavy metals and ensure sustainable farming practices.

Declarations

Acknowledgments

The Director of the Institute of Life Science (ILS), Bhubaneswar, is thanked by the authors for providing the necessary lab facilities for the SEM photographs.

Funding

We have not received any funds for the investigation

Authors' Contributions

RKP: conceptualization, writing-original draft; DPP: formal analysis and editing. GS: conceptualization, SN: data curation. MD: review and editing

Ethical Approval*

Not applicable

Consent to Participate*

All authors have participated in the investigation

Consent to Publish*

All authors have agreed to publish the work

Competing Interests

Authors declare that they don't have any conflict of interest in this work.

Data Availability Statement

Data will be available on formal request

References

1. Albatrni H, Qiblawey H, El-Naas MH (2020) Comparative study between adsorption and membrane technologies for the removal of mercury. Sep and Puri Techn 257: 117833. <https://doi.org/10.1016/j.seppur.2020.117833>
2. Aliprandini P, Veiga MM, Marshall BG, Scarazzato T, Espinosa DC (2020) Investigation of mercury cyanide adsorption from synthetic wastewater aqueous solution on granular activated carbon. J Water Pro Eng 34: 101154. <https://doi.org/10.1016/j.jwpe.2020.101154>

3. Boening DW (2000) Ecological effects, transport, and fate of mercury: a general review. *Chemosph* 40(12): 1335–1351. [https://doi.org/10.1016/s0045-6535\(99\)00283-0](https://doi.org/10.1016/s0045-6535(99)00283-0)
4. Bowman KL, Lamborg CH, Agather AM (2019) A global perspective on mercury cycling in the ocean. *The Sci Total Envir* 710: 136166. <https://doi.org/10.1016/j.scitotenv.2019.136166>
5. Elbaz A, Wei Y Y, Meng Q, Zheng Q, Yang ZM (2010) Mercury-induced oxidative stress and impact on antioxidant enzymes in *Chlamydomonas reinhardtii*. *Ecotoxic* 19(7): 1285–1293. <https://doi.org/10.1007/s10646-010-0514-z>
6. Fatima G, Raza AM, Dhole P (2025) Heavy Metal Exposure and its Health Implications: A Comprehensive Review. *Indian J Clin Biochem*. <https://doi.org/10.1007/s12291-025-01322-3>
7. Fayez KA, Bazaid SA (2013) Improving drought and salinity tolerance in barley by application of salicylic acid and potassium nitrate. *J Saudi Soc Agri Sci* 13(1): 45–55. <https://doi.org/10.1016/j.jssas.2013.01.001>
8. Ganesan K, Xu B (2017) A critical review on phytochemical profile and health-promoting effects of mung bean (*Vigna radiata*). *Food Sci Human Well* 7(1): 11–33. <https://doi.org/10.1016/j.fshw.2017.11.002>
9. Gong Y, Chen X, Wu W (2024) Application of Fourier transform infrared (FTIR) spectroscopy in sample preparation: Material characterization and mechanism investigation. *Adv Sample Prep* 11. <https://doi.org/10.1016/j.sampre.2024.100122>
10. Gusev EY, Zotova NV (2019) Cellular Stress and General Pathological Processes. *Curr Pharm Des* 25(3):251-297. doi: 10.2174/1381612825666190319114641
11. Khan SA, Khan SB, Khan LU, Farooq A, Akhtar K, Asiri AM (2018) Fourier Transform Infrared Spectroscopy: fundamentals and application in functional groups and nanomaterials characterization. In Springer eBooks (pp. 317–344). https://doi.org/10.1007/978-3-319-92955-2_9
12. Kumar B, Smita K, Flores LC (2013) Plant-mediated detoxification of mercury and lead. *Arabian J Chem* 10: S2335–S2342. <https://doi.org/10.1016/j.arabjc.2013.08.010>
13. Kurzyna-Szklarek M, Cybulska J, Zdunek A (2022) Analysis of the chemical composition of natural carbohydrates – An overview of methods. *Food Chem* 394: 133466. <https://doi.org/10.1016/j.foodchem.2022.133466>
14. Lee JH, Jeon JK, Kim SG, Kim SH, Chun T, Imm J (2011) Comparative analyses of total phenols, flavonoids, saponins, and antioxidant activity in yellow soybeans and mung beans. *Inter J Food Sci Techn* 46(12): 2513–2519. <https://doi.org/10.1111/j.1365-2621.2011.02775.x>
15. Li S, Zheng H, Sui N, Zhang F (2024) Class III peroxidase: An essential enzyme for enhancing plant physiological and developmental process by maintaining the ROS level: A review. *Internat J Biol Macromol* 283: 137331. <https://doi.org/10.1016/j.ijbiomac.2024.137331>
16. Memon A, Kusur F, Memon M (2021) Metal Hyperaccumulator Plants and Their Role in Phytoremediation. In: Prasad, R. (eds) *Phytoremediation for Environmental Sustainability*. Springer, Singapore. https://doi.org/10.1007/978-981-16-5621-7_1

17. Nandi A, Yan L, Jana CK, Das N (2019) Role of catalase in Oxidative Stress- and Age-Associated Degenerative diseases. *Oxidat Med Cell Long* 2019: 1–19. <https://doi.org/10.1155/2019/9613090>
18. Pavithra KG, SundarRajan P, Kumar PS, Rangasamy G (2022) Mercury sources, contaminations, mercury cycle, detection and treatment techniques: A review. *Chemosp* 312: 137314. <https://doi.org/10.1016/j.chemosphere.2022.137314>
19. Pérez-Gálvez A, Viera I, Roca M (2020) Carotenoids and chlorophylls as antioxidants. *Antioxid* 9(6): 505. <https://doi.org/10.3390/antiox9060505>
20. Rice KM, Walker EM, Wu M, Gillette C, Blough ER (2014) Environmental mercury and its toxic effects. *J Prev Med Pub Health* 47(2):74–83. <https://doi.org/10.3961/jpmph.2014.47.2.74>
21. Wang Y, Sun X, Peng J, Li F, Ali F, Wang Z (2024) Regulation of seed germination: ROS, epigenetic, and hormonal aspects. *J Advan Res* <https://doi.org/10.1016/j.jare.2024.06.001>
22. Weydert CJ, Cullen JJ (2009) Measurement of superoxide dismutase, catalase, and glutathione peroxidase in cultured cells and tissue. *Nat Prot* 5(1): 51–66. <https://doi.org/10.1038/nprot.2009.197>
23. Yu R, Barkay T (2022) Microbial mercury transformations: Molecules, functions, and organisms. *Adva App Microbio* 31–90. <https://doi.org/10.1016/bs.aambs.2022.03.001>

Figures

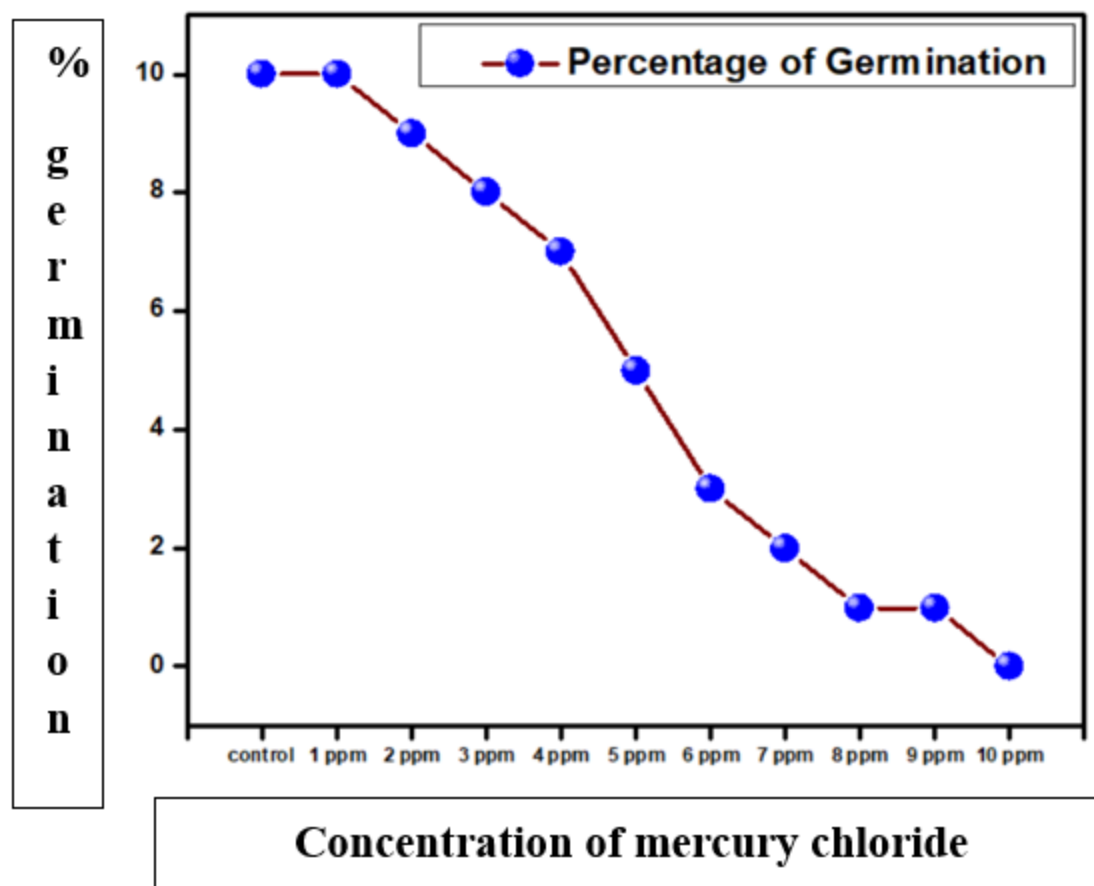


Figure 1

Effect of mercury chloride on seed germination of *Vigna radiata* plants for 7 days: (A): control, (B): 1 ppm, (C): 2 ppm, (D): 3 ppm, (E): 4 ppm, (F): 5 ppm, (G) 6 ppm, (H) 7 ppm, (I) 8 ppm, (J) 9 ppm and (K)10 ppm

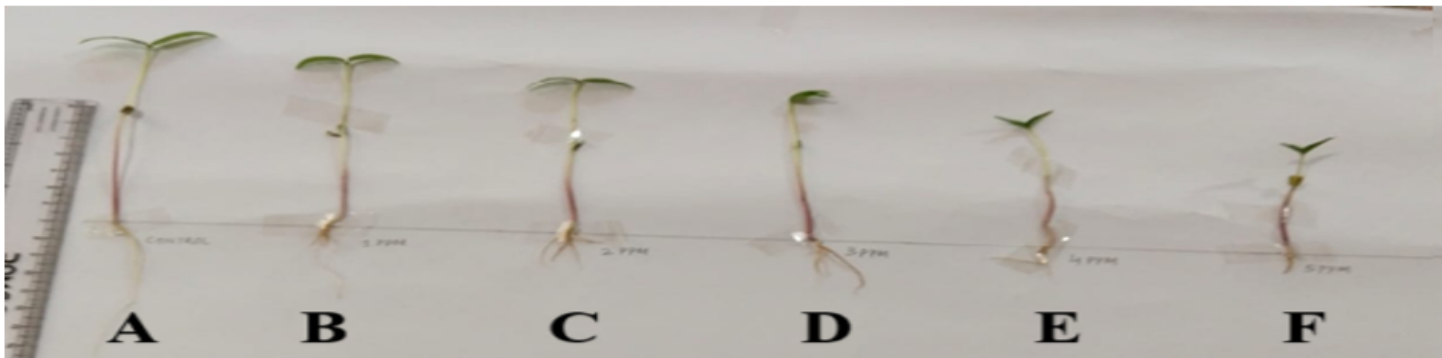


Figure 2

Morphology of *Vigna radiata* plants treated with mercury chloride for 7 days (A): control, (B): 1 ppm, (C): 2 ppm, (D): 3 ppm, (E): 4 ppm and (F): 5 ppm.

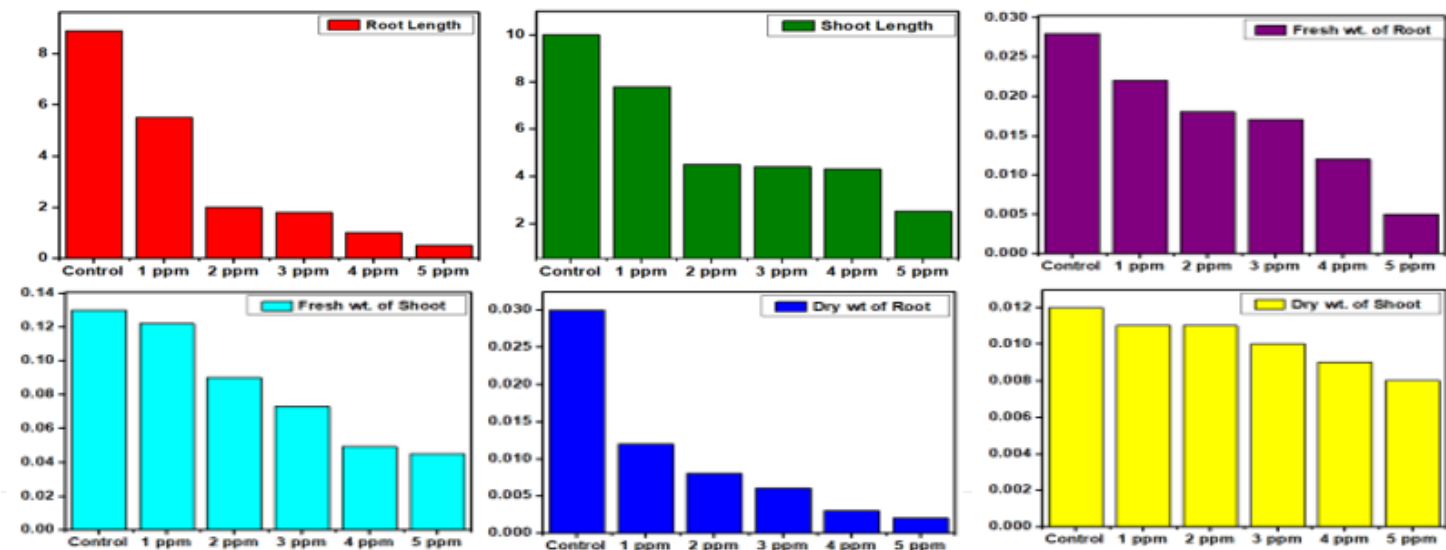


Figure 3

Effect of mercury chloride on various morphological parameters of *Vigna radiata* plants grown for 7 days (A): control, (B): 1 ppm, (C): 2 ppm, (D): 3 ppm, (E): 4 ppm and (F): 5 ppm.

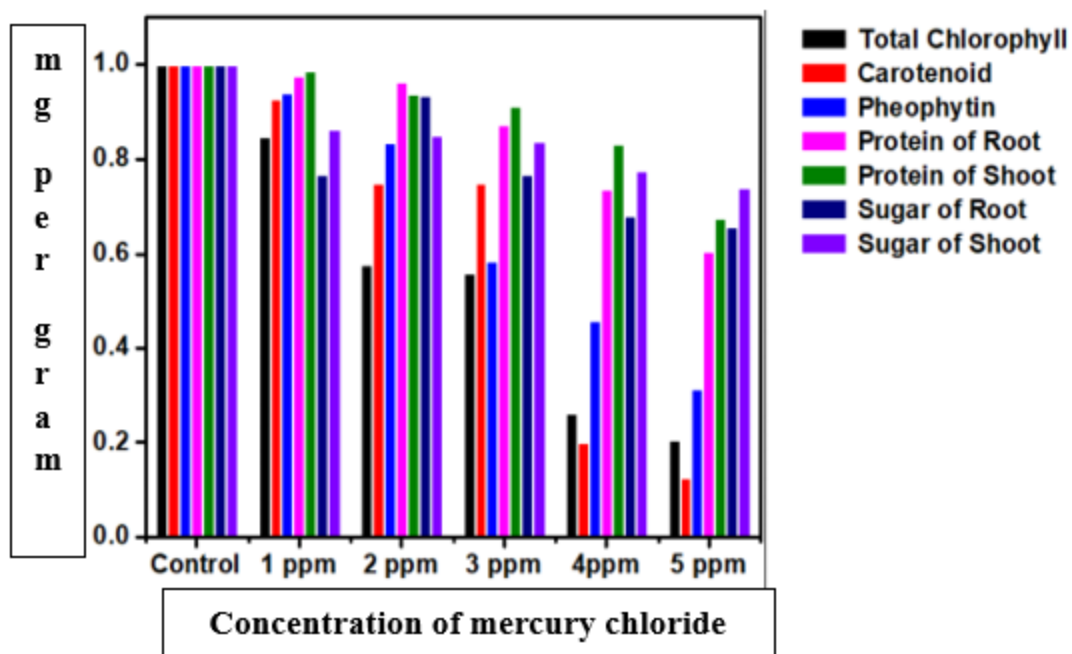


Figure 4

Effect of mercury chloride on biochemical parameters of *Vigna radiata* plants grown for 7 days (A): control, (B): 1 ppm, (C): 2 ppm, (D): 3 ppm, (E): 4 ppm and (F): 5 ppm.

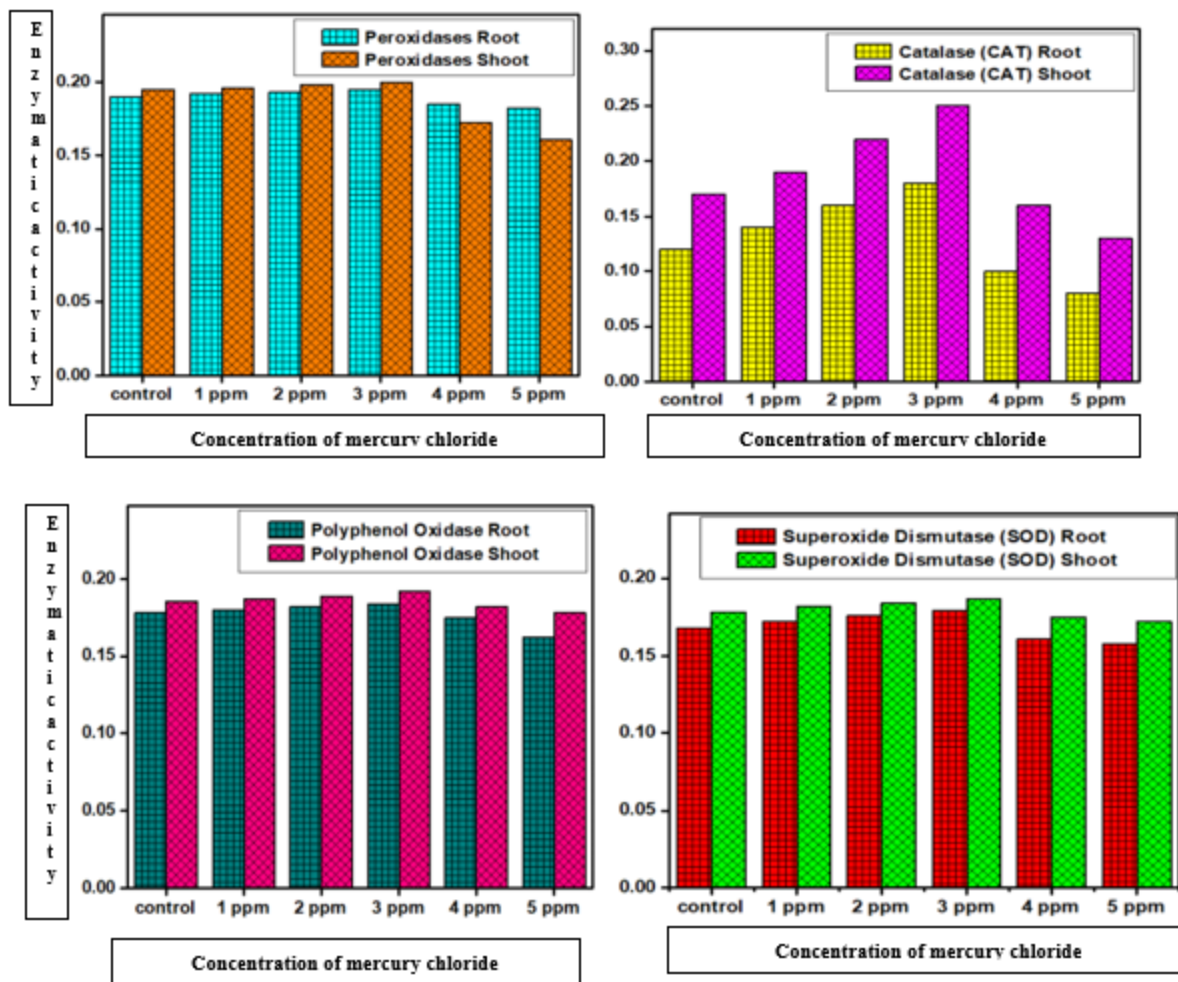


Figure 5

Effect of mercury chloride on the enzymatic activity of *Vigna radiata* plants grown for 7 days (A): control, (B): 1 ppm, (C): 2 ppm, (D): 3 ppm, (E): 4 ppm and (F): 5 ppm.

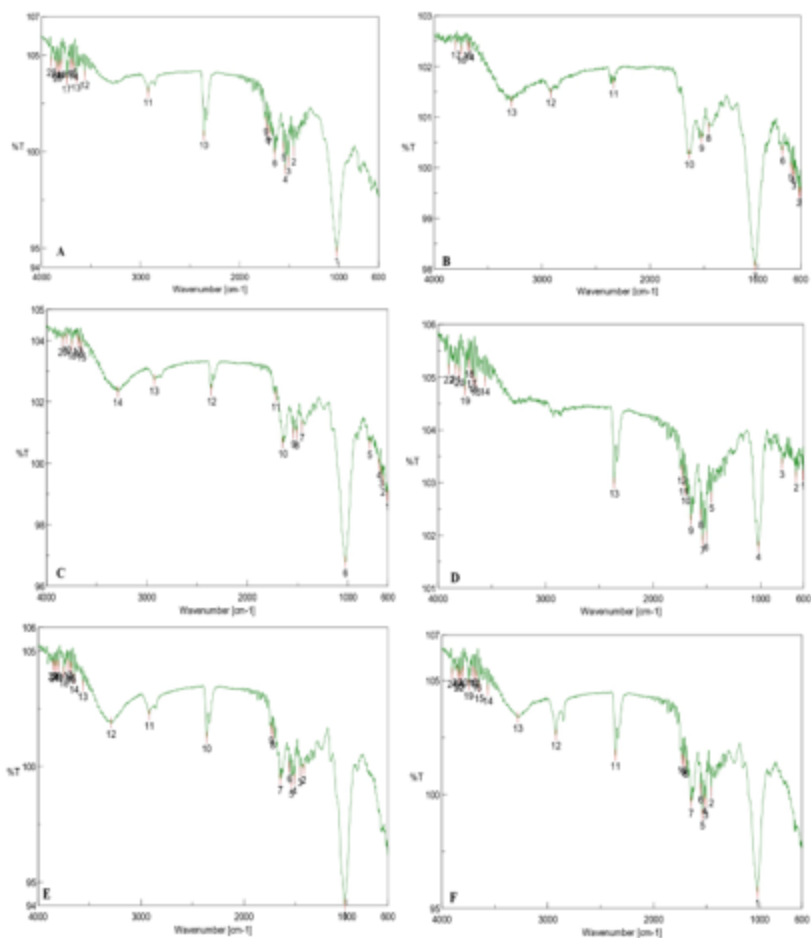


Figure 6

FTIR analysis of root of *Vigna radiata* plant grown *in vitro* treated with mercury chloride for 7 days A) control B) 1 ppm C) 2 ppm D) 3 ppm E) 4 ppm F) 5 ppm

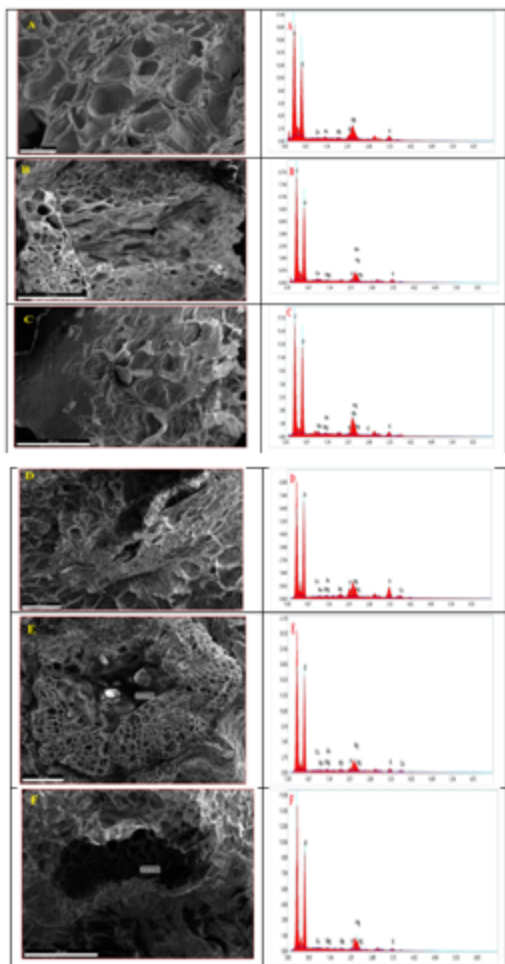


Figure 7

Scanning electron microscopy micrographs of roots of *Vigna radiata* plants treated for 7 days with mercury: (A): control, (B): 1 ppm, (C): 2 ppm, (D): 3 ppm, (E): 4 ppm and (F): 5 ppm. The energy dispersive spectroscopy shows the Hg peaks (Max peak=3.12k and Least peak=0.85 k).

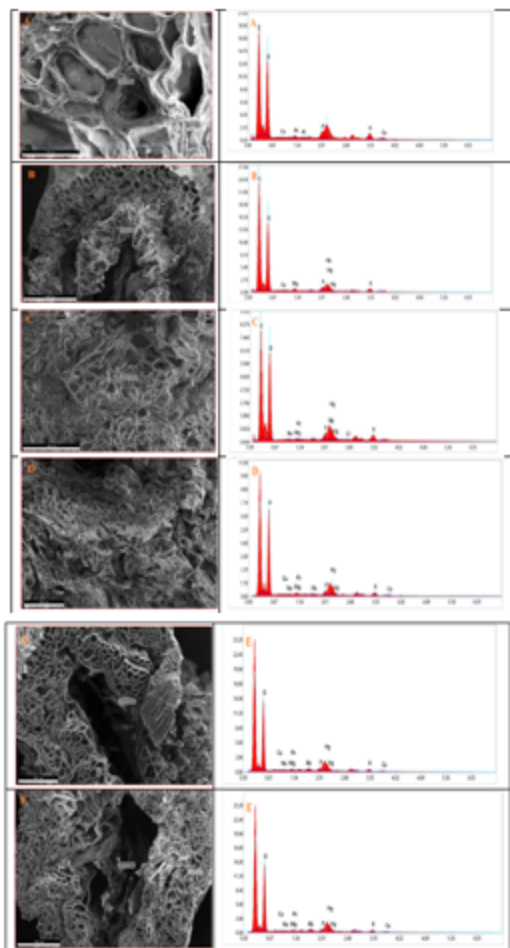


Figure 8

Scanning electron microscopy micrographs of stems of *Vigna radiata* plants treated for 7 days with mercury: (A): control, (B): 1 ppm, (C): 2 ppm, (D): 3 ppm, (E): 4 ppm and (F): 5 ppm. The energy dispersive spectroscopy shows the Hg peaks (Max peak=1.9k and Least peak=1.0k).