Mercury effects on the early seedling of *Paraserianthes falcataria* (L.) Nielsen grew in hydroponic culture

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**Abstract.** The purpose of this research was to investigate the impact of various level of mercury on the early seedling growth of sengon, *Paraserianthes falcataria* (L.) Nielsen using hydroponic culture. The study was carried out in twenty replications under greenhouse condition. The mercury used in this study were provided as chloride salts. Eight concentrations (30, 40, 50, 60, 70, 80, 90 and 100 μM) were used in this study. For each treatment, the pH was adjusted to 4.5. Fourteen-day-old seedlings were exposed to HgCl₂. Shoot and roots system of control and mercury-stress plants were harvested after 7 days of treatment. Seedling response to mercury stress was observed in the plant parts on the 3rd day after the treatment, and become severe on the 7th day. Results showed that 30 and 40 μM, the concentrations had minimum inhibitory effects on the seedling growth, respectively. The results also revealed both shoot and root dry weight of the treated seedling were sharply reduced as the mercury concentration increased to 60 μM. In a concentration of 70–100 μM the biomass dry weight was not much different. Research results show this plant can be considered as a strong candidate for a phytoremediation agent.

**Keywords:** Mercury effects, *Paraserianthes falcataria* (L.), hydroponic culture

1. **Introduction**

Plants in nature have to deal with various types of abiotic and biotic stresses. Abiotic stress is one of the factors that cause a decrease in crop productivity. At present, a very concerning environmental problem is the heavy metal pollution. Soil, water, and even air are polluted by heavy metals due to the rapid growth of industrialization, the use of different fertilizers, pesticides, and herbicides in the agricultural fields [1]. Heavy metals such as Fe, Mn, Cu, Ni, Co, Cd, Zn, Hg and arsenic accumulated in the soils through human activities [2].

Mercury (Hg) is an element that is less abundant on earth [3]. Typical normal soils usually contain 20–150 ppb mercury [4]. Increasing levels of mercury in the soil are often caused by the use of fertilizers, lime, and livestock manures. The amount of mercury presents in the soil and its absorption by plants depends on several variables such as soil pH, soil aeration, cation-exchange capacity, and plant species. The absorption can be reduced when the soil’s pH is high [5, 6].

Plants have the ability to extract, concentrate, and accumulate various heavy metals from soil and water whether or not they are needed for growth [7]. Factors that influence the absorption and accumulation of heavy metals in plant tissues include temperature, moisture, organic matter, pH, nutrient...
availability and plant species [8, 9]. The stage of plant development and the field condition will determine the sensitivity of plants to heavy metals [10].

*Paraserianthes falcataria* (L.) Nielsen or sengon is a fast-growing, nitrogen-fixing, easily cultivated plant. This plant can grow on a wide range of soils. It can grow well on dry or damp soils and saline to acid soils as long as the drainage is sufficient [11]. As a legume plant that can fix nitrogen, this plant usually planted for reforestation [12]. Based on those characteristics, we assume this plant can be used as a phytoremediator in Hg-polluted soils. This study aims to examine the mercury effects on the early seedling of *P. falcataria* L. Nielsen that could become a supporting data for the potential use of this plant as a phytoremediator.

2. Materials and method

The *P. falcataria* pre-germinated seeds were imbibed in warm water at room temperature overnight. The seeds were sown on plastic pots containing zeolite media for fourteen days. After fourteen days in the zeolite, the seedlings were transferred into a rectangular tank filled with 20 L of full-strength Hoagland media solution containing Ca(NO₃)₂, KNO₃, KH₂PO₄, MgSO₄, Fe-EDDHA, MnSO₄, ZnSO₄.7H₂O, CuSO₄.5H₂O, H₂BO₃ and (NH₄)₆ Mo₇ O₂₄.4H₂O. The pH was adjusted to 5.6 and replaced with fresh solution every two days. Each plastic tank contained 20 seedlings. After seven days of adaptation, the seedlings were treated with different HgCl₂ concentrations: 30, 40, 50, 60, 70, 80, 90 and 100 μM for 7 days. Each concentration of HgCl₂ was added to half-strength Hoagland nutrients solution in an individual plastic tank.

This study was performed in the greenhouse at the Faculty of Mathematics and Natural Sciences, Universitas Indonesia from April to May 2019. The average daytime temperature during April to May 2019 is 28.1 °C. Observations were conducted daily to record changes in leaf color and condition, such as curling and wilting. Fallen leaves were gathered for further analysis. After the completion of the study, *P. falcataria* seedlings were harvested by separating the shoots and roots for weighing the wet weight (WW). And then, the samples were dried in an oven for 48 h at 65 °C to obtain dry weight (DW). Relative water content was calculated as, RWC (%) = [(WW - DW)/WW] x 100 [13].

3. Results and discussion

Hg-induced toxicity in plants causes a decrease in growth. *P. falcataria* seedlings treated to various levels of HgCl₂ demonstrated a slowing off of root and shoot growth after 7 days of treatment. Results showed that the 30 and 40 μM Hg concentrations had minimum inhibitory effects on the seedling growth, respectively. Plant biomass is a good indicator for assessing the growth conditions of plants exposed to heavy metal. The resulting study showed that mean root and shoot weight were different in the Hg treatment plants as compared with the control. The decreased root and shoot and of the treated plants (figure 1) demonstrated the severe impact of Hg concentrations on growth (both in shoots and roots) of *P. falcataria* seedlings, comparable to the wheat plant biomass decline patterns reported in Sahu et al. [14].

Plants exposed to heavy metal toxicity show symptoms of stunted growth, leaf chlorosis, and root browning [15]. Symptoms of damage will depend on the affected area. Mercury ions can enter together with water and bind aquaporin to prevent water entry to plants. Plants experience oxidative stress due to membrane damage that is triggered by disruption of the electron transport chain in the mitochondria and chloroplast [16]. The addition of 30 μM Hg did not cause changes in leaf color or seedling conditions. Plants exposed to Hg do not indicate symptoms of toxicity up to 30 μM Hg. At higher Hg concentrations (60–100 μM) toxicity symptoms appear such as chlorosis, drying of leaf margins, curly leaves, browning of roots, and falling leaves (figure 2). The seedlings developed leaf chlorosis on day 4 after the administration of HgCl₂. On day 5, all leaves begin to wilt and experience an earlier aging. After day 7 the administration of HgCl₂ was stopped because the plant died. The ability to accumulate
and tolerance of plants to heavy metals varied from one species to another, some shows symptoms of toxicity earlier than others.

Figure 1. The wet and dry weight of shoot and root of *P. falcataria* seedlings which grown for 7 days in presence of HgCl$_2$ in hydroponic cultures.

Figure 2. Mercury toxicity symptom in *P. falcataria* seedling grown in half-strength Hoagland solution with the addition of 30–100 μM HgCl$_2$. 

Abiotic stress that strikes plants induces metabolic and physiological disruption [17], thereby reducing plant fitness productivity [18]. Abiotic stress is one of the stressors that have an impact on growth and is responsible for decreasing yield. In most plant species the percentages of growth reduction can reach more than 50 [19]. In this study, the decline in biomass indicates that photosynthesis is disrupted. Hg exposure can reduce chlorophyll synthesis, photosynthesis rate, transpiration, and water absorption because it is related to Hg which causes loss of potassium, magnesium, manganese, and iron. Magnesium and iron are needed to synthesize chlorophyll [20].

Figure 3 shows that the addition of higher levels of Hg caused the lower biomass production of *P. falcataria* plants. Hg$^{2+}$ at concentrations from 40 to 100 μM caused a 66% reduction in biomass.

The growth of the roots of the plant being in direct contact with the media is more affected compared to the shoot. In the present study, the plant biomass fresh and dry weight started to decline at a concentration of 30 μM, but there was only a slight different between 40 until 90 μM.

Plant growth and development are reduced because plants are lack of water, triggered by the accumulation of Hg ions in cells [21]. As an indicator of phytotoxicity, we measured the Relative Water Content (RWC). The RWC of our samples appears to be fluctuating but shows a downward trend. Starting at the treatment of 30 μM Hg there was a decrease in the range of 2–4% (table 1). Relative water content is slightly higher in 30 μM Hg-treated plants than in the control. Similar patterns also occur in grass pea *Lathyrus sativus* which treated with lead. The addition of Pb might cause the stomata to close, and the atmospheric carbon fixing activities is disrupted [22].

Figure 3. Mercury (HgCl$_2$) effect on fresh and dry weight biomass of *Paraserianthes falcataria* L. seedlings.

| Hg concentration (μM) | Biomass Fresh Weight (g) | Biomass Dry Weight (g) | Relative Water Content (%) |
|-----------------------|--------------------------|------------------------|---------------------------|
| 0                     | 5.82                     | 1.98                   | 65.98                     |
| 30                    | 4.05                     | 1.3                    | 67.90                     |
| 40                    | 2.33                     | 1.07                   | 54.08                     |
| 50                    | 2.02                     | 0.95                   | 52.97                     |
| 60                    | 2.06                     | 0.95                   | 53.88                     |
| 70                    | 1.74                     | 0.87                   | 50.00                     |
| 80                    | 2.17                     | 0.93                   | 57.14                     |
| 90                    | 1.94                     | 0.97                   | 50.00                     |
| 100                   | 2.47                     | 0.93                   | 62.35                     |
At the cellular level, Hg metal ions will bind with ligands containing sulfur and nitrogen (amino acids) to enter the cell. The damage due to mercury includes blocking the functional groups of enzymes, polynucleotides, or transportation systems for nutrient ions, denaturing and inactivating enzymes, damaging cells and disrupting the integrity of the organelle’s membrane. One of the causes of mercury toxicity is the change in cell membrane permeability and the replacement of essential ions with Hg ions [23].

With enzyme denaturation, membrane damage, water deficit, and disruption of carbon fixation activities, photosynthesis are greatly reduced, which results in a decrease in plant biomass. But from the observations, not all plants show a stress response. Some individual plants are still healthy, namely the treatment of 30 μM and 100 μM (figure 2). This shows that some sengon plants can adapt and tolerate Hg.

4. Conclusion
The present research indicated that increasing Hg$^{2+}$ concentrations in the nutrient solution decreases both root and shoot biomass. The results also revealed both shoot and root dry weight of the treated seedling were reduced as the mercury concentration increases to 60 μM. At a concentration of 70 –100 μM the biomass dry weight was not much different. Based on the results of the study, more research is needed to ensure the possibility of *P. falcataria* (L.) Nielsen to become a phytoremediation agent because this study uses plants that are still in the early seedling phase.

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