Research Article

Effect of Heavy Metals on Vegetative Growth, Flower Production and Chemical Characteristics of *Cassia glauca*

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Abstract |Egyptian cinnamon, also known as *Cassia glauca*, belongs to the legume family (Fabaceae) and the genus Cassia. It is a small ornamental shrub prized for its attractive foliage, distinctive shape, and bright yellow flowers. In addition to its striking beauty, *Cassia glauca* is also used for its medicinal benefits. Heavy metals have emerged as a major environmental threat to the global ecosystem, particularly to plant communities. They are among the most damaging abiotic stressors due to their high atomic weight and non-biodegradable nature, which allows them to accumulate and persist in the environment. Lead is one of the oldest metals used by humans, and although its use has declined globally, it remains common in industrial applications such as battery production. Widely distributed in soil, air, water, and living organisms, lead is considered one of the most toxic environmental pollutants, second only to elements like arsenic. Cadmium is also dangerous, posing serious risks to plant health due to its ability to affect nutrient absorption and metabolic processes, ultimately leading to poisoning. The current experiment was conducted in Babylon Governorate to study the effects of heavy metals—particularly lead and cadmium—on vegetative growth, flower production, and the chemical properties of *Cassia glauca*. The study also aimed to assess the plant's tolerance to stress associated with heavy metal contamination. Taken together, it is plausible to conclude that adding heavy elements (lead and cadmium) to the soil resulted in a significant decrease in all studied indicators.

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Introduction

Cassia glauca is a small, flowering shrub with compound green leaves and bright yellow flowers. It blooms year-round, but is most abundant in spring, summer, and autumn. *Cassia glauca* is a butterfly-attracting plant and a favorite nesting site for them. Tropical Asia and northeastern Australia are considered the native habitat of *Cassia glauca*. *Cassia glauca* grows well in desert conditions, with direct sunlight and high temperatures, provided the plant is well maintained in terms of watering. If the plant is used as a flowering hedge, it is necessary to prune it. It should also be pruned when used as a tall, single-stemmed tree or as a plant barrier on a support. When left to grow without pruning, the plant becomes massive, with slender branches and smooth, olive-green bark. The plant grows well and thrives in acidic to slightly alkaline soils that are rich in organic matter and nutrients. Cassia is used as an ornamental, flowering plant, and as a medicinal plant because it contains medicinal compounds and substances. Because it is one of the legumes, Egyptian cinnamon has the ability to fix atmospheric nitrogen, enabling the plant to provide its own nitrogen (Abdlkareem and Kadhim., 2023). Heavy metals are a group of persistent, non-biodegradable inorganic chemical compounds which affects cells by poisoning them, and it has genetic effects. Heavy metals also cause changes that lead to mutations in humans, plants and animals, by affecting food chains and affecting these chains through their pollution, as well as polluting the soil, drinking water and irrigation water.

There are two types of metals in soil, the first type is known as micronutrients that are essential for normal plant growth, such as iron, manganese, zinc, copper, nickel, molybdenum, and magnesium. The second type is known as secondary or non-essential elements that have known biological properties functions, such as cadmium, anthocyanins, chromium, lead, arsenic, cobalt, silver, selenium, and mercury (Zhou *et al*., 2014). Both are subterranean, the places above ground for plants are capable of receiving heavy metals, plants need them in trace amounts to help it grow and develop, as well as for metabolic processes Thus, the concentration of both essential minerals and non-essential minerals is one of important factor in plant growth, such that their excess presence can reduce and inhibit plant growth. Lead (Pb) is a mineral that humans use for thousands of years (Gupta *et al*., 2020: Alwan *et al*., 2025; Talib *et al*., 2025). and is primarily used in batteries. Pb is found in soil, as well as in water, air, and living organisms, and Lead is also one of the elements which causes effects on living organisms in the environment due to its toxicity (Shahid *et al*., 2011). Lead is considered the most serious contaminant after arsenic, due to its important physical and chemical properties. Lead in natural environments is not very mobile and tends to accumulate in soil surface horizons. It has no physiological role and remains toxic even at low doses. The damage caused by lead to plants depends on the severity of lead exposure and the duration of exposure, the stage of the plant's life, the target organ, and the plant species and even the plant variety (Bozziani *et al*., 2023). Cadmium (Cd) element is a metal that is harmful to living organisms and contaminates agricultural ecosystems. Cadmium accumulation in soil comes from many sources, such as the increased use from fertilizers, smelting, mining, chemical manufacturing and pesticides. Because cadmium is highly mobile in the soil and easily soluble in water, it is easily absorbed by plants. Furthermore, cadmium causes toxic damage to plants during the growth and development stages and poses a health risk to humans and other living organisms through interfering with food chains. Therefore, remediating cadmium-contaminated soil is of paramount importance (Wang *et al*., 2024).

The aim of this work is to assess the impact of Cassia plants' tolerance for heavy metal stress (lead and cadmium). Additionally, we aim to assess the extent of the effect of heavy elements on the vegetative growth characteristics, flower production and chemical properties of the Egyptian Cassia plant.

Materials and Methods

The experiment was conducted in a private nursery in the Center of Babil Governorate, during the 2024-2025 growing season. *Cassia glauca* seedlings, one and a half months old, were of uniform height (50 cm for all seedlings), after being transferred from a 22 cm diameter anvil to a 29 cm diameter anvil. A medium of organic fertilizer and peat moss (3:1) was used. The purpose of the experiment was to determine the tolerance of *Cassia glauca* to cadmium and lead stress. In addition, the aim was to determine the harmful effects of lead and cadmium on the vegetative characteristics, flower production, and chemical properties of Egyptian *Cassia glauca*. Before planting, soil samples were examined, and chemical and physical analyses were performed before planting, as shown in Table 1.

Experimental Implementation

The experiment was conducted to study the tolerance of cassia plants to lead and cadmium stress, as well as to determine the effect of heavy metals (lead and cadmium) on the development of the apical parts and flower production of cassia plants. The plants were irrigated with lead nitrate and cadmium nitrate, and the interactions between them were determined as follows: 1. Standard treatment without added pollutants, designated as M0. 2. Lead nitrate treatment at a level of 300 mg of lead/kg soil, designated as M1.

3. Cadmium nitrate treatment at a level of 10 mg of cadmium/kg soil, designated as M2. 4. Combined treatment with lead nitrate and cadmium nitrate at concentrations of 300 and 10 mg of lead and cadmium/kg soil, respectively, designated as M3.

Table 1: *A number of chemical and physical properties of the soil in which the plants were grown.*

Value	Units	Traits
0.37	Lt\Kg of dry soil	Saturation rate
0.28	Lt\Kg soil	Field capacity of anvil
93	%	Sand
3		Clay
6	%	Grain percentage
2.70	ms/cm	Electrical conductivity EC
6.4	--------	pH
20.4	ppm	available nitrogen in soil
7.5	ppm	Soil available phosphorus
9.7	ppm	Potassium available in soil
6.19	ppm	Total lead in soil
0.33	ppm	Total cadmium in soil
0.28	ppm	Ready lead in soil
0.08	ppm	Ready Cadmium in soil

Experimental design

The factorial experiment (4 × 4) was conducted using the randomly distributed complete plots (R.C.B.D) implementation. There were three replicates of the experiment, each replicate containing 16 treatments, and four seedlings for each treatment, where the total number of plants reached 192. The least significant difference (LSD) test was used at a probability level of 0.05% to compare the means (Verdooren *et al.*, 2020).

Results and Discussion

Average of plant height (cm. plant-1)

As shown in Table heavy metals negatively affected plant height, as the lead treatment negatively affected the average plant height, which reached 84.62 cm compared to the standard treatment (91.44 cm) The table also showed a negative effect of cadmium on the average plant height, which reached 82.06 cm compared to the standard treatment, that gave 91.44 cm. The table also showed that the interaction between lead and cadmium recorded the lowest average plant height, which reached 78.54 cm, compared to the standard treatment (91.44 cm).

Number of leaves (Leaf per plant)

The results shown in Table 2 indicate that heavy metals negatively affected the number of leaves per plant, as the lead treatment recorded an average number of leaves per plant of 38.65 leaves/plant compared to the control treatment (50.80 leaves/plant). In addition, the results showed that cadmium negatively affected the average number of leaves per plant, as it recorded 41.26 leaves/plant compared to the standard treatment, which gave 50.80 leaves/plant. The statistical analysis also showed that the interaction between lead and cadmium recorded the lowest average number of leaves per plant, which amounted to 37.83 leaves/plant compared to the standard treatment.

Table 2: *Effect of heavy metals (lead and cadmium) and their interactions on vegetative and floral traits of Cassia glauca.*

Number of leaves Leafe. plant^{-1}	Plant hight CM	Heavy metal (H.M)
50.80	91.44	Control (H.M.)
38.65	84.62	Lead (Pb)
41.26	82.06	Cadmium (Cd)
37.83	78.54	Pb+Cd

The results showed a significant effect of heavy metals, as lead, cadmium, and their interactions negatively affected vegetative traits (plant height and number of leaves per plant (Table 2). This is due to the fact that toxic heavy metals accumulate highly in vegetative leaves and the root system, inhibiting metabolic and vital processes, such as photosynthesis, disrupting the function of some enzyme systems, and preventing protein and chlorophyll synthesis. In this regard, Chauhan and Mathur, 2020 have observed that cadmium and lead stress in sunflower plants significantly preserved the activity of the growth regulator glutathione reductase. Similarly, Ma *et al.*, 2018 have reported. heavy metals cause toxic effects by increasing the accumulation of reactive oxygen species (ROS) and methylglyoxal (MG), which oxidize lipids and proteins, inhibit enzyme function, damage DNA, and interact with numerous cellular components in plant cells (Lajayer *et al.*, 2019). These harmful effects have been reported, suggesting that heavy metals can disrupt plant metabolic processes, such as photosynthesis by inhibiting water uptake, impeding nitrogen accumulation, halting respiration, disrupting transcription, and possibly disrupting the activities of various enzymes. They combine with sulfhydryl (SH-) groups and increase the production of reactive oxygen species (ROS), causing oxidative stress. Furthermore, Mamand *et al.* (2020) have reported that lead also negatively affects mitochondrial structure by reducing their peaks, thus diminishing their capacity for oxidative phosphorylation (Nofal *et al.*, 2022).

Flowering date (Day)

The results in Table 3, indicate that lead did not significantly change the flowering date, while cadmium had a significant effect in reducing the number of days to flowering, as cadmium recorded 176.34 days compared to the control treatment. The interaction between lead and cadmium resulted in the lowest number of days for the plant to flower, reaching 176.22 days, compared to the control treatment (178.89 days).

Number of inflorescences (inflorescences per plant)

The results show that heavy metals negatively affected the number of inflorescences per plant (Table 3). Lead negatively affected the average number of inflorescences, reaching 18.71 inflorescences per plant, compared to the standard treatment, which produced 24.19 inflorescences per plant. In addition, cadmium had a negative effect on the number of inflorescences, reaching 16.96 inflorescences per plant, compared to the control treatment, which produced 24.19 inflorescences per plant. The interaction between lead and cadmium resulted in the lowest number of inflorescences per plant, reaching 15.58 inflorescences per plant, compromising the standard treatment, which produced 24.19 inflorescences per plant.

Analysis also showed significant results for heavy metals, as lead, cadmium, and their interaction negatively affected floral characteristics (flowering date and inflorescence number). Due to the toxicity caused by lead when added to the soil, the number of flowers per plant decreased with increasing lead concentrations in Tagetes erecta (Table 2). According to Ma *et al.*, 2022, different lead concentrations significantly affected the number of flowers in three hydrangea cultivars, and each cultivar reacted differently to heavy metal stress with increasing lead concentrations. With increasing lead concentrations, the number of flowers decreased in 'Endless Summer', while it increased in 'Classic Rood' and 'Ayesha'. In the study conducted on Salvia splendens Sello cv. 'Torreador', flowering was not affected by lead treatments, and the highest number of inflorescences was recorded at the highest lead concentration of 200 mg lead. dL-1 (Nowak, 2007). This discrepancy between studies is believed to be due to differences in species, cultivars, soil lead content, and application method. In fact, heavy metal ingestion by plants depends on both soil conditions and plant factors. The mechanism of lead phytotoxicity involves different biochemical trends in different plant species (Bektaş and Özyazici, 2024). Furthermore, the addition of cadmium to agricultural soils significantly reduced floral traits. This is due to decreased photosynthetic efficiency and water evaporation resulting from stomatal closure and decreased carbon dioxide entry into plant tissues due to cadmium toxicity. This may also be due to disruption of the balance in enzyme activity and inhibition of cell division, which negatively affects plant growth (Almuwayhi, 2021).

Table 3: *Effect of heavy elements (lead and cadmium) and their interaction on the floral characteristics of Cassia glauca.*

Heavy metal (H.M.)	Flowering date day	Number of influ-ences
Control (H.M.)	178.89	24.19
Lead (Pb)	177.26	18.71
Cadmium (Cd)	176.34	16.96
(Pb)+ (Cd)	176.22	15.58

Nitrogen percentage in leaves (%)

The results show that heavy metals negatively affected the percentage of nitrogen in plant leaves (Table 4). The lead treatment negatively affected the average percentage of nitrogen in plant leaves, with a value of 1.83% compared to the standard treatment, which gave 1.95%. In addition, the table showed the negative effect of cadmium on the average percentage of nitrogen in plant leaves, with a value of 1.67% compared to the standard treatment, which gave 1.95%. The same table showed that the combination of lead and cadmium recorded the lowest average percentage of nitrogen in plant leaves, reaching 1.41%, compared to the standard treatment, which gave 1.95%.

Phosphorus percentage in leaves (%)

Data in the Table 4 indicate that heavy metals negatively affected the percentage of phosphorus in plant leaves. The lead treatment negatively affected the average percentage of phosphorus in the leaves, with a value of 0.27% compared to the standard treatment, which gave 0.42%. In addition to the above, the table showed the negative effect of cadmium on the average percentage of phosphorus in the leaves, as its value reached 0.19% compared to the standard treatment, which gave 0.42%. The table also showed that the interaction between lead and cadmium recorded an average percentage of phosphorus of 0.19%, compared to the control treatment, which gave 0.42%.

Table 4: *Effect of heavy elements (lead and cadmium) and their interaction on the chemical properties of Cassia glauca*

K%	P%	N%	Heavy metal (H.M.)
1.45	0.42	1.95	Control (H.M.)
1.03	0.27	1.83	Lead (Pb)
0.98	0.19	1.67	Cadmium (Cd)
0.96	0.19	1.41	(Pb)+ (Cd)

Percentage of potassium in leaves (%)

As indicated in the Table 4, heavy metals negatively affected the percentage of potassium in plant leaves. The lead treatment negatively affected the average percentage of potassium in the leaves, reaching 1.03% compared to the standard treatment, which gave 1.45%. The table also showed the negative effect of cadmium on the average percentage of potassium in the leaves, reaching 0.98% compared to the standard treatment, which gave 1.45%. The table also showed that the interaction between lead and cadmium recorded the lowest average percentage of potassium in the leaves, which amounted to 0.96%, compared to the standard treatment, which gave 1.45%.

Heavy metals have a significant impact, as lead and cadmium, along with their interactions, negatively affected chemical properties (nitrogen, phosphorus, and potassium content) (Table 4). This is because the addition of lead has significant negative effects on the nutrient content of the vegetative system. Heavy metals generally affect the increase in plant cell size, as well as their development and the amount of beneficial minerals in them. This effect of heavy metals is closely related to genetic factors, and the process of transporting heavy metals from the root system to the vegetative system varies among the same species, not just between different species. It is believed that the differences in results obtained in studies are due to different plant responses or different genotypes to metal stress (Sağlam Koçak & Gül, 2023). A decrease in nutrients was observed with increasing cadmium toxicity, as its high levels affect the absorption and accumulation of nutrients. Cadmium has been shown to interfere with the absorption, transport, and utilization of many nutrients. The absorption of nutrients by plants is also negatively affected by cadmium, as it affects the availability of nutrients in the soil (Al-Muwaihi, 2021).

Conclusions

Adding heavy elements (lead and cadmium) to the soil resulted in a significant decrease in all studied indicators, in addition to the combined negative effect between them, as the mixture (lead and cadmium) achieved the greatest significant decrease in all studied indicators.

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Novelty Statement

This study uniquely evaluates combined chemical and biological control strategies—specifically integrating Estrats pesticide with Beauveria bassiana and Bacillus thuringiensis—using multiple application methods against Ommatissus lybicus on date palms. It provides the first comparative field evidence from Iraq demonstrating superior efficacy of spray-based integrated treatments for sustainable Dubas bug management.

Author's Contibution

Mohammed Adnan Jawad: Each contributed to formulating the research idea and solving the research problem, participated in conducting the experiment, interpreting the results, and writing the paper.
Janan Kaasim Hussein: Each contributed to formulating the research idea and solving the research problem, interpreted the results and reviewed the paper.
This work was completed collaboratively by all authors.

Generative AI and AI-assisted technology statement

Generative artificial intelligence or AI-assisted techniques were not used in the preparation, writing, or editing of this manuscript.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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