Effect of different levels of heavy metals on some growth indicators and yield of yellow corn *Zea mays* L.

Ammar Dalal Hasan Mahdi

Ministry of Education, Wasit Education Directorate, Wasit , Iraq

*Corresponding author's email: dalalamar69@gmail.com

Abstract

Heavy metals are dangerous environmental pollutants. Their danger lies in their cumulative properties in the bodies of living organisms and they cause harm to humans when they consume food contaminated with them. The aim of study was to estimate effect of different levels of heavy metals on some growth indicators and yield of yellow corn *Zea mays*. Three concentration have been used in this experiment including 0, 20, 40, 60 mg. kg soil. The results showed that significant differences the highest average height of 82.37 cm and cadmium yielding the lowest at 75.60 cm. Add different concentrations of heavy metals has affected on chlorophyll in *Zea mays*. There is a significant differences was found, with the average nickel metals giving the highest value at 116.11 and the average cadmium metals giving the lowest value at 114.73. Finally, significant differences were observed, with the cadmium concentration reaching the highest value at 13.90 g and the average nickel concentration at the lowest was 12.98 g. The heavy metals negatively affect stem growth, biomass accumulation, and consequently the yield.

Keywords: heavy metals, yield, yellow corn, *Zea mays*

Introduction

Heavy metals are dangerous environmental pollutants. Their danger lies in their cumulative properties in the bodies of living organisms and they cause harm to humans when they consume food contaminated with them. Also, the excessive accumulation of heavy metals in the soil is a result of natural or unnatural activities such as the use of sewage and industrially polluted water, or as a result of air deposits resulting from car and factory exhaust, or chemical materials such as dyes, medicines, agricultural chemicals, production and packaging waste from factories, detergents, petrochemicals, and waste from hospitals, homes, slaughterhouses, and farms. All these factors lead to raising the concentrations of heavy metals, especially in the surface layer of the soil [1].

These metals have harmful effects on the plant's appearance, including stunting, failure to achieve fertilization, and reduced growth and development of root hairs, which hinders and stops growth due to a decrease in the plant's photosynthesis rate as a result of stomata blockage due to metals precipitation, inhibition of enzyme activities, disruption of water balance, and changes in the selective permeability of cell membranes, as well as disturbances in nutrient absorption [2]. The danger that threatens both the environment and human health resulting from these sites necessitates the application of strategic processes aimed at removing these pollutants, limiting their spread, and

ISSN 2072-3857

reducing their impact. Phytoremediation is the least expensive and environmentally friendly process for reclaiming the soil and ridding it of hazardous and polluting metals [3].

Zea mays play an important role in treating the soil from heavy and toxic metals by breaking down some of the complex chains of hydrocarbon compounds and increasing soil oxidation and absorption of heavy metals [4]. This is reflected positively on the chemical and physical properties of the soil through the accumulation of heavy metals in the shoot system and the root system [5]. The absorption process of heavy metals occurs within the root system of the plant through special mechanisms designed for this purpose, which represent a large part of the biological processes that reduce the toxicity of these metals in the soil contaminated with them [6]. Therefore, the aim of study was to estimate effect of different levels of heavy metals on some growth indicators and yield of yellow corn *Zea mays*.

Materials and Methods

Heavy metals in soil (Ni, Cd) were estimated by atomic absorption spectroscopy at the construction laboratory after wet digestion of the samples using an acidic mixture ($HClO_4$: HNO_3). The concentrations of the metals were then measured using an atomic absorption spectroscopy (AAS).

The crop (local variety) was planted on 7/15/2025 in the previously prepared pots to which heavy metals were added at the concentrations mentioned in paragraph 3-1. Water was added to the limits of the field capacity and left for more than 21 days for the purpose of balance. Then they were thinned to five plants and nitrogen fertilizers were added to them in two applications. Irrigation was carried out after the consumption of 50% of the prepared water and the experiment continued until the plant reached the stage of maturity, i.e., a period of approximately three months.

The total content of heavy metals (Cd, Ni) was estimated after digesting the foliage and root samples with a mixture of the two acids (HCLO4-H2SO4). This was done by taking 0.5 g of the dried sample and sifting it through a 2 mm sieve and placing it in a 250 ml Pyrex bottle. Then, 5 ml of concentrated sulfuric acid (H2SO4) was added and left for 24 hours. The samples were then placed on a hot plate at a temperature of 80°C for one hour. The samples were then air-cooled, and 3 ml of perchloric acid (HCLO4) was added at a temperature of 180°C for 2-3 hours until the color changed from dark brown to clear and colorless. After that, it was filtered through Whatman filter paper and the volume was made up to 50 ml with distilled water.

Studied characteristics of *Zea mays*

Leaf Area (cm^2/plant):

The leaf area of *Zea mays* was calculated at full flowering (100%) for the same three plants used to measure plant height, and the overall average was calculated using the following equation:

$$Leaf\ Area = (Length\ of\ leaf\ below\ main\ ear)^2 \times 0.75$$

Chlorophyll Content

The chlorophyll content at flowering stage was estimated using a SPAD chlorophyll meter. Readings were taken from three

ISSN 2072-3857

leaves of each plant, and the average was calculated for three plants from each of two plants.

Plant Height (cm)

The average plant height of three plants from each pot at flowering stage for yellow corn was measured. The height of the yellow corn plant was measured from the soil surface to the top of the plant using a ruler, and the average was calculated. The average height of the corn plant was then calculated for three plants from each pot.

Number of seeds

It was calculated by sorting the seeds counting them manually. It included both full and empty seeds.

Plant yield (g)

After separating the heads from the plant at the stage of full crop maturity, each plant was air-dried, and the weight of the yellow corn seeds was calculated after the heads were separated. Then the weight was adjusted based on moisture content (12%).

Statistical Analysis

The Statistical Analysis System (SAS) 2001 software was used to analyze the data according to a randomized complete block design (RCBD). Significant differences between means were compared using the Least Significant Difference (LSD) test at a probability level of 0.05.

Results and Discussion

Plant height (cm)

The results showed significant differences in all metals; with lead yielding the highest average height of 82.37 cm and cadmium yielding the lowest at 75.60 cm. Significant differences were also observed among all treatments, with treatment control yielding the highest height of 81.88 cm compared to treatment T3, which yielded the lowest height of 62.35 cm. Furthermore, the interaction effect of the two metals revealed significant differences, with treatment control yielding the highest height at 81.88 cm and treatment T3 yielding the lowest height of nickel at 74.63 cm.

This is because to the toxicity of heavy metals when absorbed by the plant, as they negatively affect various metabolic activities and inhibit the activity of essential enzymes. Heavy metals are essential for the synthesis of growth hormones such as auxins and gibberellins, which play crucial roles in regulating plant growth and development. Inhibiting these hormones hinders cell elongation and division, leading to a general cessation of plant growth (Hassan et al., 2022). They also reduce the frequency of cell division in meristematic regions, causing delayed root development. This results in weak root extension and limits the plant's ability to absorb nutrients, thus reducing overall plant growth (Mocquot et al., 1996). This is also attributed to the ability of heavy metals to restrict plant growth through several mechanisms, including inhibiting protein synthesis, negatively impacting photosynthesis, and impeding carbohydrate transport within plant cells, leading to a significant decline in plant growth [7].

ISSN 2072-3857

Table (1) Effect of heavy metals on the height of *Zea mays* yields (cm)

Treatments	heavy metals		Average
	Cd	Ni	
Control	81.88	82.87	82.37
T1	80.90	79.66	80.28
T2	77.72	73.20	75.46
T3	61.90	62.80	62.35
Average	75.6	74.63	
LSD 0.05	0.10	0.98	

Leaf area (cm²/plant)

There is a significant differences was found, with the average nickel metals giving the highest value at 116.11 and the average cadmium metals giving the lowest value at 114.73. The results also showed significant differences between all treatments, with treatment control giving the highest value at 183.25 compared to treatment T3, which gave the lowest value at 72.67. The results of the interaction effect between metals removal and the level of addition also showed significant differences, with treatment control giving the highest value at 189.10 (Table 2).

This is attributed to the effect of cadmium on the absorption and transport of essential nutrients such as calcium and magnesium, which are important and vital metals for leaf growth. Its structure and the deficiency of these metals may lead to deformities in the leaves and a change in their shape [8]. High levels of heavy metals in the soil can cause wilting of leaves and other parts of the plant, often as a result of oxidative stress and cell damage caused by exposure to heavy metals. Metals can stimulate the production of certain reactive oxygen species in plant cells, causing damage to cell components, including proteins, lipids, and DNA, which leads to the breakdown of cellular structures and organelles and the appearance of necrotic lesions on the affected tissues. Nickel can reduce the electron transport process in photosynthesis and reduce the synthesis of adenosine triphosphate (ATP) in chloroplasts [9].

Table (2) Effect of heavy metals on the leaf area of *Zea mays* yields (cm²/plant)

Treatments	heavy metals		Average
	Cd	Ni	
Control	189.10	177.40	183.25
T1	112.88	110.30	111.59
T2	90.40	97.95	94.17
T3	66.55	78.80	72.67
Average	114.73	116.11	
LSD 0.05	4.60	9.88	

ISSN 2072-3857

Chlorophyll content

Table (3) shows the effect of adding different concentrations of heavy metals on chlorophyll in *Zea mays* plants. The results showed no significant differences, with the average nickel concentration giving the highest value at 37.15 and the average cadmium concentration the lowest at 36.40. The results also showed significant differences between all treatments, with treatment control giving the highest value at 44.65 compared to treatment T3, which gave the lowest value at 30.35. The results of the interaction effect between the type of metals and the level of addition showed significant differences, with treatment control giving the highest cadmium concentration at 30.50 and treatment T3 giving the lowest at 30.20.

Heavy metals have ability to inhibit several enzymes and metabolic pathways involved in chlorophyll synthesis. By disrupting the delicate balance of chlorophyll synthesis, lead-induced leaf yellowing manifests as a gradual yellowing in cereal crops. Nickel's ability to weaken the plant's capacity to absorb light and produce carbohydrates can lead to reduced photosynthetic capacity and leaf yellowing. Altered leaf structure may also affect stomatal conduction and transpiration, potentially resulting in water loss. This affects chlorophyll, as concluded by [10]. Cadmium can inhibit chlorophyll synthesis in several ways. It inhibits the activity of enzymes involved in chlorophyll synthesis, thus impairing the conversion of precursor molecules into functional chlorophyll molecules. Consequently, chloroplasts within damaged leaf cells become chlorophyll-poor, leading to a noticeable loss of green color [11]. Cadmium can also inhibit the enzymes ALAD and PPO, both essential for chlorophyll production. Inhibition of these enzymes disrupts the chlorophyll synthesis pathway [12].

Table (3) Effect of heavy metals on the Chlorophyll content of *Zea mays*

Treatments	heavy metals		Average
	Cd	Ni	
Control	44.10	45.20	44.65
T1	38.90	40.33	39.61
T2	32.10	32.90	32.5
T3	30.50	30.20	30.35
Average	36.40	37.15	
LSD 0.05	1.10	2.66	

Number of Seeds

The results show the effect of adding different concentrations of heavy metals on the number of seeds in a *Zea mays* plant. The results showed significant differences, with the average nickel metals giving the highest value at 23.45 and the average cadmium metals giving the lowest value at 23.12. The results also showed significant differences between treatments, with treatment control giving the highest value at 79.09, compared to the T3, all of which gave

ISSN 2072-3857

the lowest value of 2.65. The results of the interaction effect between the type of metals and the level of addition also showed significant differences, with treatment control giving the highest value 80.88, while the other treatments gave the lowest value of 2.10 and 3.20 for both metals (Table 4). The toxicity of heavy metals affects the overall growth performance of the plant, which is reflected in its productivity by inhibiting root growth, leading to weakened plant cells. Heavy metals also affect water balance and nutrient absorption, complicating the process of transporting resources to the upper parts of the plant. The heavy metals negatively affect stem growth and biomass accumulation, and consequently the yield [3]. The role of cadmium and nickel in disrupting the physiological, chemical, and biological processes of the plant [7].

Table (4) Effect of heavy metals on the seeds number of *Zea mays* yields

Treatments	heavy metals		Average
	Cd	Ni	
Control	80.88	77.30	79.09
T1	6.20	7.10	6.65
T2	3.30	6.20	4.75
T3	2.10	3.20	2.65
Average	23.12	23.45	
LSD 0.05	2.10	2.55	

Plant Yield (g)

The results indicate that the effect of adding different concentrations of heavy metals on the yield of *Zea mays*. Significant differences were observed, with the average cadmium concentration reaching the highest value at 13.90 g and the average nickel concentration at the lowest at 12.98 g. Significant differences were also found between treatments, with treatment control yielding the highest value at 36.85 g, compared to all other treatments, which yielded the lowest value of 2.30. Furthermore, the interaction between the type of metals and the level of addition revealed significant differences, with treatment control yielding the highest value 37.80 g, while all other treatments yielded the lowest value of 0 (Table 5).

This is because to the role of cadmium, and nickel in disrupting the physiological, chemical, and biological processes of the plant [13]. Heavy metal toxicity affects the overall growth performance of the plant, which is reflected in its productivity by inhibiting root growth, leading to weakening of the plant's cell structure. Heavy metals also affect water balance and nutrient absorption, complicating the process of transporting resources to the upper parts of the plant, which negatively affects stem growth and biomass accumulation. This is what [14] concluded.

ISSN 2072-3857

Table (5) Effect of heavy metals on the plant yield of *Zea mays* (g)

Treatments	heavy metals		Average
	Cd	Ni	
Control	37.80	35.90	36.85
T1	10.33	8.20	9.26
T2	5.40	5.33	5.36
T3	2.10	2.50	2.3
Average	13.90	12.98	
LSD 0.05	2.10	2.55	

Conclusions

The study concludes that significant differences the highest average height of 82.37 cm and cadmium yielding the lowest at 75.60 cm. Add different concentrations of heavy metals has affected on chlorophyll in *Zea mays*. There is a significant differences was found, with the average nickel metals giving the highest value at 116.11 and the average cadmium metals giving the lowest value at 114.73. The heavy metals negatively affect stem growth, biomass accumulation, and consequently the yield.

References

[1] Abedinzadeh, M., Etesami, H., & Alikhani, H. A. 2019. Characterization of rhizosphere and endophytic bacteria from roots of maize (*Zea mays* L.) plant irrigated with wastewater with biotechnological potential in agriculture. Biotechnology Reports, 21, e00305.

[2] Aliu, S., Gashi, B., Rusinovci, I., Fetahu, S., & Vataj, R. 2013. Effects of some heavy metals in some morpho-physiological parameters in maize seedlings. American Journal of Biochemistry & Biotechnology, 9(1), 27.

[3] Aly, A. A., & Mohamed, A. A. 2012. The impact of copper ion on growth, thiol compounds and lipid peroxidation in two maize cultivars ('*Zea mays*' L.) grown'in vitro'. Australian journal of crop science, 6(3), 541-549.

[4] Atif, M., & Perveen, S. 2021. Comparison of alteration in growth, physiological and biochemical attributes of ten maize (*Zea mays* L.) varieties under arsenic stress: susceptibility and tolerance. Polish Journal of Environmental Studies, 30(6).

[5] Atta, M. I., Zehra, S. S., Ali, H., Ali, B., Abbas, S. N., Aimen, S., Sarwar, S., Ahmad, I., Hussain, M., & Al-Ashkar, I. 2023. Assessing the effect of heavy metals on maize (*Zea mays* L.) growth and soil characteristics: Plants-implications for phytoremediation. PeerJ, 11, e16067.

[6] El Dakak, R. A., & Hassan, I. A. 2020. The alleviative effects of salicylic acid on physiological indices and defense mechanisms of maize (*Zea Mays* L. Giza 2) stressed with cadmium. Environmental Processes, 7(3), 873-884.

ISSN 2072-3857

[7] Hassan, A., Parveen, A., Hussain, S., Hussain, I., & Rasheed, R. 2022. Investigating the role of different maize (*Zea mays* L.) cultivars by studying morpho-physiological attributes in chromium-stressed environment. Environmental Science and Pollution Research, 29(48), 72886-72897.

[8] Mocquot, B., Vangronsveld, J., Clijsters, H., & Mench, M. 1996. Copper toxicity in young maize (*Zea mays* L.) plants: effects on growth, mineral and chlorophyll contents, and enzyme activities. Plant and soil, 182(2), 287-300.

[9] Ruiz-Huerta, E. A., Armienta-Hernández, M. A., Dubrovsky, J. G., & Gómez-Bernal, J. M. 2022. Bioaccumulation of heavy metals and As in maize (*Zea mays* L) grown close to mine tailings strongly impacts plant development. Ecotoxicology, 31(3), 447-467.

[10] Sagar, A., Sayyed, R., Ramteke, P. W., Ramakrishna, W., Poczai, P., Al Obaid, S., & Ansari, M. J. 2022. Synergistic effect of Azotobacter nigricans and nitrogen phosphorus potassium fertilizer on agronomic and Yieldtraits of maize (*Zea mays* L.). Frontiers in Plant Science, 13, 952212.

[11] Shafi, Z., Shahid, M., AlGarawi, A. M., Zeyad, M. T., Marey, S. A., Hatamleh, A. A., Wang, S., & Singh, U. B. 2024. The exogenous application of 24-epibrassinolide (24-EBL) increases the Cd and Pb resilience in *Zea mays* (L.) by regulating the growth and physiological mechanism. Applied Biochemistry and Biotechnology, 196(7), 3949-3973.

[12] Shafique, F., Ali, Q., Yasin, G., Ahmad, S., Shafeeq, T., Zaheer, A., & Malik, A. 2020. Heavy metal toxicity and it's physio-biochemical effects on maize (*Zea mays* L.). Plant Cell Biotechnology and Molecular Biology, 21(45-46), 94-102.

[13] Suganya, A., Saravanan, A., & Manivannan, N. 2020. Role of zinc nutrition for increasing zinc availability, uptake, yield, and quality of maize (*Zea mays* L.) grains: An overview. Commun. Soil Sci. Plant Anal, 51(15), 2001-2021.

[14] Yang, N., Wang, H., Wang, H., Wang, Z., Ran, J., Guo, S., & Peng, Y. 2021. Screening maize (*Zea mays* L.) varieties with low accumulation of cadmium, arsenic, and lead in edible parts but high accumulation in other parts: a field plot experiment. Environmental Science and Pollution Research, 28(25), 33583-33598.

ISSN 2072-3857