Phytotoxicity of Some Heavy Metals Through Five Different Wheat Genotypes

M. M. EL-Fakharany [1,*], A. I. H. Sayed [2], R. A. R. EL Said [1], F. S. AL-Anany [1], and R.I. EL-kholy [2].

[1] *Department of Biological and Environmental Sciences, Faculty of Home Economics, Al- Azhar University, Tanta, Egypt.,*

[2] *Agriculture-Botany (Genetics) Department, Faculty of Agriculture, Al-Azhar University, Cairo11884, Egypt.*

*Corresponding author E-mail: *marwaelfakharany290@azhar.edu.eg*. (M. EL-Fakharany)

ABSTRACT:

Hexaploid wheat contains 42 chromosomes while tetraploid wheat contains 28 chromosomes. Chromosomal behavior affected with heavy metal treatments. Heavy metal causes chromosomal abnormalities. Heavy metals as a toxic substances reduce the respiratory ratio and biosynthetic process. The phytotoxicity of heavy metals liberal through human activities reduces crop growth and yield. The current investigation was conducted to evaluate the effect of some heavy metals; Effect of cadmium [Cd], zinc [Zn], copper [Cu] and lead [Pb] on the growth of five different wheat genotypes at different stages of growth under field conditions. The results exhibited that heavy metals have a significant effect on some growth and yield traits. Cadmium had the least significant effect on plant traits, followed by zinc, copper and lead. Wheat genotypes differed in their response to heavy metal stress. Furthermore, it can be accomplished that the wheat genotype Beni Suef 5 had the highest tolerance to metals followed by Gemmayzeh 12 and Beni Suef 6, while Sakha 94 and Misr 1 showed the least tolerance to metals. Tolerant genotypes at different growth stages can be used commercially under heavy metal stress and can also be used as donor varieties to develop promising varieties intended for agricultural production under heavy metal stress.

Keywords: *Triticum aestivum* L.**;** Cadmium; Zinc; Copper; Lead**.**

INTRODUCTION

Wheat is a staple food crop for about 36% of the world's population. Wheat is a major component of human diets, but about 10% of wheat is retained by industry (for the production of starch, malt, paste, gluten and dextrose,). Heavy metal (HM) toxicity has been a global concern in recent years and is a serious threat to the environment and human health. In the case of plants, a high concentration of heavy metals negatively affects cellular metabolism due to the generation of reactive oxygen species (ROS) that target key biological molecules Riyazuddin, *et al*. (2021).

Plants use different strategies to relieve the negative effect of HM toxicity by reducing the uptake of these HMs and sequestering them into the vacuoles with the help of different molecules including proteins like phytochelatins, metallothioneins, compatible solutes, and minor metabolitesRiyazuddin, *et al*. (2021). reported that the toxic effect of HM can be observed on all plant tissues and at all stages of the plant life cycle from grain germination to maturity; Moreover, these effects are more pronounced during grain germination and root growth. Since seed germination is sensitive to physical and chemical conditions of the rhizosphere, a reduction in seed germination, vigor and subsequent seedling growth under HM toxicity has been observed in most cases (Adrees *et al*. 2015).

Such as many plants, wheat is also sensitive to heavy metals (Staniˇsi´c Stoji´c *et al.* 2016). When heavy metals enter plants, stress leads to various effects in plants, ranging from germination and growth, to biochemical effects and reduced wheat productivity Sindhu *et al*. (2015). Naturally, the plant requires major elements for growth. Although these trace elements are fundamental, exposure to heavy metals can hardly damage plants. The effect of heavy metals on plants begins in the root zone, where metals and mineral substances interact with root exudates (Alengebawy *et al*. 2021).

Cadmium is an unnecessary and dangerous heavy metal, and the accumulation of cadmium in plants leads to toxic effects that can inhibit the transport of iron to plant shoots (Schützendübel *et al*. (2002); Jibril *et al*. (2017). Cadmium has a toxic effect on plant morphology (eg, reduction of plant weight and length of roots and shoots), cytotoxicity (eg, reduction of chlorophyll content and inhibition of photosynthetic performance), and metabolic processes (eg, chlorosis and cell damage). Stolt *et al*. (2006) who studied the performance of different genotypes of wheat in Cadmium absorption. Genetic differences in Cadmium accumulation occurred due to different physiological and morphological traits of the genotypes.

Zinc may have substantial role in various metabolic processes, like photosynthesis, respiration, and the assimilation of other major nutrients, and in the activation of antioxidant enzymes, Saifullah *et al*. (2016). It is indicated that the accumulation of zinc in the roots or shoots of plants causes serious damage, as an excessive increase in zinc in plant cells leads to a major disturbance in the physiological processes in plants, followed by the death of the plant (Liang and Yang 2019).

The plant needs a small amount of Cu for plant nutrition and seed production. However, at high concentrations, Cu is a highly toxic metal, (Wuana and Okieimen. 2011; Chiou and Hsu. 2019). Adrees *et al*. (2015) reported that Cu toxicity led to a decrease in crop yield, chlorophyll biosynthesis, and plant productivity by modifying photosynthesis and nutrients.

Lead (Pb) is among the heavy metals is the second most harmful pollutant after arsenic and was recently listed as the "Chemical of great concern"" according to new European REACH regulations Pourrut *et al*. (2011). It strongly influences normal plant metabolism, physiological traits, crop growth and yield (Sharma and Dubey 2005; Ashraf *et al*. 2015). Pb is not major for plant growth (Diaconu *et al*. 2020). It is classified as a major pollutant due to its high toxicity Chauhan *et al*. (2020). Normally, lead ions are transported from the soil to the plant via the roots through the xylem Gupta *et al*. (2019).Lead toxicity is dangerous to plants even at low concentrations, which hinders good plant growth and reduces crop yield and productivity Ashraf *et al*. (2017). In general, lead reduced morphological traits, like length (shoot and root), fresh and dry biomass of shoots, and number of tillers/ plant. Therefore, the aim of this study was to study the polluting effects of heavy metals (cadmium, zinc, copper and lead) on some morphological traits (botanical and yield characteristics) of wheat cultivars with atrophic level.

MATERIALS AND METHODS

This study was conducted at the Faculty of Home Economics, Al-Azhar University; during 2020 & 2023, aimed to study the pollution effects of some heavy metals on five different genotypes wheat with aretrophic level.

Experimental design:

Five replicates of each genotype, with a total of 325 pots with 15 cm x 18 cm each containing 2.600 kg of soil.

Plant material:

The five wheat cultivars selected for this investigation. Grains of the material involved in the current study were kindly obtained from Field Crops Research Institute, Agricultural Research Center, Giza.

The five wheat genotypes from the Poaceae family; two genotypes of *durum* wheat and three of *aestivum* wheat were named as; Beni Suef 5, Beni Suef 6 (T. *durum*) and Gemmayzeh 12, Sakha 94, Misr 1 (T. *aestivum*).

Experimentation:

The conducted experiment consists of three treatments of Cd, Zn, Cu & Pb; with five replicates for the selected genotypes and control. With three concentrations for each metal in which, three hundred twenty-five pots. Grains were planted first in seedling trays with soil consisting of peat moss and sand washed in a ratio of 1:1 for a period of 20 days for groups of five varieties, with a total of 20 seedling trays, and they were irrigated with tap water every five days. Seedlings were transferred to the pots on the 21st day of seedling by10 seedlings of each genotype for each replicate. The potting experiments were conducted in a natural environment system (from November to April) for a period of six months. Periodic irrigation with tap water is resumed every five days until the 40th day of planting. Irrigation was carried out using treatments by adding heavy metals to the irrigation water according to the concentrations shown below, with a total of three times per week. The first treatment was at the 41st day of cultivation. Each pot was irrigated with about half a liter of heavy metal treated water. Periodic irrigation with tap water starting 58 days is resumed every five days until the plant reaches the pasty stage.

Preparation of stock solution:

Standard solutions of Cd, Zn, Cu and Pb were prepared by dilution of 1000ppm certified standard solutions as Jamali, *et al*. (2009).

To prepare desired Cadmium concentrations. It is used to prepare the desired cadmium stock by dissolving 1.95 g of cadmium chloride (CdCl2.H2O) in 1000 ml of distilled water. A volume of 30 liters of water for irrigation, using a pipette with a capacity of 1 ml and drawing an amount of stock as follows:

The first concentration Cd_1 0.01 Ppm by adding 0.3 ml / 30 liters.

The second concentration is Cd_2 0.05 Ppm by adding 1.5ml / 30 liters.

The third concentrate Cd_3 0.1 ppm by adding 3 ml / 30 liters.

Salts of Zinc chloride ($ZnCl^2$), Copper chloride ($CuCl_2.2H_2O$) Lukšienė & Račaitė (2008) and Lead Acetate ($C_4H_6O_4$ Pb) with high purity (99.0%) were used to prepare desired metals concentrations. To prepare the desired stocks by dissolving 2.1 g, 2.77 g and 1.569 g, respectively, in 1000 ml of distilled water. The concentrations of the three treatments for each metal of them are obtained for a volume of 30 liters of water for irrigation, as follows;

The first concentration Zn_1, Cu_1 and Pb_1(5 Ppm) by adding 150 ml / 30 L.

The second concentration is Zn_2, Cu_2 and Pb_2(10 Ppm) by adding 300 ml /30 L.

The third concentrate Zn_3, Cu_3 and Pb_3(15 Ppm) by adding 450 ml / 30 L.

All the plants were fertilized twice at day 27 and 66 of the age of the plants using granular urea fertilizer 46% nitrogen by dissolving 2 g of fertilizer / 0.5 liter of tap water for each pot.

Vegetarian characteristics of wheat varieties:

shoot height

Using a ruler from the surface of the soil to the end of the plant, the height of the plants was measured in cm, which were taken for the five wheat varieties for all treatments, at the age of 85 and 115 days from sowing, before starting to expel the spikes and at the milky stage, respectively. The data were recorded and statistical analysis was performed after obtaining the averages of the readings and testing the significance of the coefficients for the items using chi-square.

Crop characteristics or (Harvest Parameters) of wheat varieties:

Whole plant samples were collected from each pot at harvest.

By using the scale data was recorded the following readings on gm for all replicates of the varieties and treatments:

1- Total weight (T.w) gm.

2- spike weight (Sp. w) gm.

3- 100 grains weight (100 G.w) gm.

Where the grains were separated from the spikes and measured the weight of 100 grains.

Statistical Analysis

Testing the significance of the treatments for the varieties was done using CHISQUARE as shown in the tables.

Statistical analysis:

The experiments were subjected to completely randomized design. Each treatment was replicated five times. Values from triplicate determinations of each sample were averaged. Data were analyzed statistically by CHI-SQUARE test, at the 5% &1% probability level.

RESULTS AND DISCUSSIONS

Heavy metals like cadmium (Cd), copper (Cu) , zinc (Zn) , lead (Pb) and chromium (Cr), are an important group of trace elements, which can adversely affect humans , animals and plants if they are in concentrations higher than normal. The results of the current study exhibited that cadmium, zinc, copper and lead have a significant effect on the plant characteristics of wheat varieties at 85&115 days (Table1,2,3&4, respectively). (T.H/ 85D* mean total height at 85 at days / T.H/ 115D** mean total height at 115 at days).

The analysis of data for Cd concentrations effect (Table 1) showed that Cd_1(0.01ppm) and Cd_3(0.1ppm) were highly effect for the height of the plants at the age of 85 days of Beni Suef 5 and Beni Suef 6, respectively, by increasing the height with 78 and 74 %, respectively, while Sakha 94 was sensitive for Cd_2(0.05 ppm) by increasing the height with 32 %, also Gemmayzeh 12 and Misr 1were sensitive to Cd_3 by increasing the height with 63 and 7 % respectively.

The same results were obtained at 115 D for the total height at the varieties; Beni Suef 6, Beni Suef 5, Sakha 94 and Gemmayzeh 12 by increasing the plant height with 190, 160, 60 and 40 %, respectively, by Cd_1 for the first variety and Cd_3 for the rest varieties, respectively, these results were agreed with Riyazuddin *et al*. (2021), Who found that tolerant plants detoxify HM toxicity by activating a complex signaling network that often culminates in the activation of a defense response involving the accumulation of (1) antioxidants to detoxify excess ROS, (2) secondary metabolites to sequester HMs in vacuoles, and (3) compatible solutes for osmoregulation as well as mineral transporter regulation, among others. Misr 1 variety was found to be shocked at Cd^1/115D and tolerant after (Cd_2&Cd_3) with no effects controlled with normal plants.

Our results in Table 2 revealed that the first concentration of Zinc (Zn_1/ 5.0 ppm) at the height of the plants sensitivity at the age of 85 days of Beni Suef 5 and Beni Suef 6, Gemmayzeh 12 and Sakha 94 and Misr 1, respectively, by increasing the height with 59, 41, 46,27 and 13 %, respectively, these results were agreed with Riyazuddin *et al*. (2021).

Meanwhile at 115 days gave that Zn_1 was affected on the sensitivity of height of the plants of Beni Suef 5 and Sakha 94, while Zn_2 (10.0 ppm) affected on Beni Suef 6, respectively, by increasing the cultivars height with 195, 57, and 160%, respectively, these results were agreed with Riyazuddin *et al*. (2021), but Zn_3(15.0ppm) affected on Gemmayzeh 12 by decreasing the height variety with 81%, this result was agreed with Mahmood *et al.* (2007), who reported in another study that a significant inhibition of shoot height of wheat was also observed with increasing Zn. Misr1 gave non-significant for Zn treatments at the height variety in age of 115 days. This result was agreed with Stolt *et al*. (2006).

Data in Table 3 revealed the effected of Cu on the same varieties, Cu_2 (10.0ppm) was highly significant at the height of the plants at the age of 85 days of Beni Suef 5 by increasing the height with 56 %, and the treatment of Cu_3(15.0ppm) was increased the plant height at the varieties of Beni Suef 6, Gemmayzeh 12 and Sakha 94 by increasing the height with 46, 21 and 6 %, respectively, these results were not agreed with Riyazuddin *et al.* (2021), who found that transport of HMs from contaminated soil via roots to aerial parts and their accumulation in plant cells directly interferes with cellular metabolism of shoots leading to a decrease in height as observed in a variety of crop and non-crop plants including wheat (Sharma & Sharma. (1993)., rice (He *et al*. (2014).

While Cu was not affected at the height of the plants at the age of 85 days the variety of Misr1 this result was agreed with Stolt *et al.* (2006).

Data in Table 3 showed that at 115 days, Cu_1 was more effected at the variety of Sakha 94 by increasing the height with 75 % and Cu_2 was the same effect at the varieties of Beni Suef 5 and Beni Suef 6 by increasing the height with 180 and 130 %, respectively. And also Cu_3 at the varieties of Gemmayzeh 12 and Misr1 by increasing the height with 34 and 25 %, respectively, these results were not agreed with Riyazuddin *et al*. (2021). But agreed with Day &Weber. (1981), who found in last study that wheat irrigated with wastewater produces taller plants and higher grain productivity than wheat mature with groundwater. Gemmayzeh 12 and Misr1 varieties reduced in its length at Cu_2 by 67 and 21%, respectively, and these results were in agreement with Adrees *et al*. (2015), who reported that copper toxicity led to a reduce in crop productivity, chlorophyll biosynthesis, and plant productivity by modifying photosynthesis and nutrients.

Our results in Table 4 suggested that, Pb_1 and Pb_2, respectively were more sensitive at the height of the plants at the age of 85 days at the varieties of Beni Suef 6 (Pb_1), Beni Suef 5 and Gemmayzeh 12 (Pb_2) by increasing the height with 53, 54 and 25 %, respectively. these results were agreed with Stolt *et al*. (2006). and Riyazuddin *et al*. (2021). While Misr1 variety was decreased the height by Pb_1 with 15 %, this result was agreed with.

Our results in Table 4 suggested that, Pb_1 and Pb_2, respectively were more sensitive at the height of the plants at the age of 85 days at the varieties of Beni Suef 6 (Pb_1), Beni Suef 5 and Gemmayzeh 12 (Pb_2) by increasing the height with 53, 54 and 25 %, respectively. these results were agreed with Stolt *et al*. (2006). and Riyazuddin *et al*. (2021). While Misr1 variety was

decreased the height by Pb_1 with 15 %, this result was agreed with.

The Zinc treatments results showed that $Zn_{3,1}$& $_3$, respectively, were affected at the total yield weight of Beni Suef 5, Sakha 94 and Misr 1 by decreasing with 21, 40 & 50 %, respectively, (Table 6), but Zn_2 was increased Gemmayzeh 12 total yield weight with 30 %. The Zn treatments were no effects (Table 6) to Beni Suef 6, these results were.

Agreed with Kirmani *et al*. (2018), who mentioned that the toxic concentration of zinc negatively affected the morphological, physiological and yield traits of wheat varieties.

As well as the spikes weight of the varieties Beni Suef 6 and Gemmayzeh 12 were decreased (8.0 %) and increased (60.0 %), respectively, by Zn_3 and Zn_2, respectively,

While Beni Suef 5, Sakha 94 and Misr 1, not effected by Zn. The same results were obtained by Kirmani *et al*. (2018).

For the 100 grains weight data in Table 6 suggested that Beni Suef 5, Beni Suef 6 and Sakha 94 were increased with 29, 43 & 20 %, respectively, by Zn_1, Zn_2 & Zn_1. Gemmayzeh 12 and Misr 1 were decreased with 7& 4%, respectively, by Zn_3. These result were agreed with Stolt *et al*. (2006). And agreed with Si-ping *et al*. (2022), who found that as the level of zinc increased, the wheat yield first increased and then decreased, indicating that treatment with a low level of zinc could increase wheat yield, while treatment with a high level of zinc could cause a decrease in yield.

The analysis of data Table 7 suggested that, Cu_1, Cu_2 & Cu_3, were severe effect on total yield weight of Beni Suef 5, Sakha 94 and Gemmayzeh 12 by decreasing with 35, 29 & 4 %, respectively, and increasing at Cu_2 in Beni Suef 5 (11.0%). These results were agreed with Agarwala & Sharma 1979, whom found that lower grain yield in low-copper plants. This is due to the reduced number of effective tillers, disturbance of grain setting and production of primitive ears in these plants. While the Cu treatments were no affects (Table 7) at Beni Suef 6, Misr 1 and the rest treatments of the previous varieties.

As well as the spikes weight of the varieties Gemmayzeh 12 and Misr 1 were increased with 7 & 4 %, respectively, in each of them at both of Cu_1 and Cu_2. These results showed that Cu treatments had no effects on all varieties. While Ghani and Naheed. (2011), reported that the plants at low copper had decreased height and profuse tillering which could be attributed to the loss of apical dominance of the main stem.

Results in Table7 showed that; although Gemmayzeh 12 was decreased with 22 % by Cu_1, results gave increasing for the 100 grains weight in Beni Suef 5(Cu_2 & Cu_3), Beni Suef 6 (Cu_1, Cu_2 & Cu_3) and Sakha 94 (Cu_2& Cu_3), respectively, with (11&11%), (26, 16 &43%) & (11& 38 %), respectively. Four of the varieties (except Beni Suef 6) by the rest of treatments were showed not affected on 100 grains weight. These results were agreed with Mussarat *et al*. (2021), whom reported that wheat grain yield significantly affected with heavy metals in the water irrigation, and reflected in the wheat grains which had about 2 folds higher heavy metals. And also agreed with Arshad *et al*. (2011), whom suggested that there was gradual increase in total biomass with increasing levels of Cu. And agreed with Ghani and Naheed. (2011), whom found that plants with low copper had reduced in length and tillering which could be attributed to a loss of apical dominance over the main stem.

Lead Pb treatments in Table 8 were gave attributed results for the total yield weight in wheat varieties, results in Beni Suef 5 (Pb_2), Beni Suef 6 (Pb_1& Pb_3) and Misr 1 (Pb_1& Pb_2) had no effected with Pb treatments. The same table gave significant decreasing at Pb_1 (Beni Suef 5), Pb_1, Pb_2 & Pb_3 (Sakha 94) and Pb_3(Misr 1) for the total yield weight with 4.0%, (7.0, 19.0 &12.0 %) and 5.0 %, respectively. These results were agreed with Sharma and Dubey. (2005), Whom reported that lead strongly affects normal plant metabolism, physiological traits, crop growth and productivity.

Table 8 also showed that Gemmayzeh 12 was increased total yield weight at all Pb treatments with 4.0, 17.0 & 8.0 % respectively, while Beni Suef 5, Beni Suef 6 increased by Pb_3 & Pb_2 with 28 &12 %, respectively.

The spikes weight was found to be more sensitive for (Pb_1, Pb_2 & Pb_3) by increasing in varieties; Beni Suef 5 with (7.0, 7.0 &7.0 %), Gemmayzeh 12 with (7.0, 27.0 &42.0 %) and Misr 1 with (4.0, 10.0 & 4.0 %), respectively. While decreasing Sakha 94 with 4.0 & 4.0 % by Pb_2& Pb_3, respectively. Only Beni Suef 6 (all treatments) and Sakha 94 (Pb_1) were not affected.

This results were agreed with Sharma and Dubey. (2005), Whom reported that lead strongly affects normal plant metabolism, physiological characteristics, crop growth and productivity. It often results in diminished growth, distortion of cellular structures, ionic homeostasis, decrease in chlorophyll biosynthesis, hormonal imbalance, and induces over-production of reactive oxygen species (ROS) in plants (Shahid *et al*., 2011; Kumar *et al*., 2012).

As for the 100 grains weight data in Table 8 showed that Beni Suef 5, Beni Suef 6, Gemmayzeh 12, Sakha 94 and, Misr 1 were increased, this result was obtained with Mussarat *et al*. (2021), whom reported that wheat grain yield was significantly affected by heavy metals in irrigation water, and this was reflected in the wheat grains that contained heavy metals about 2 times higher.

REFERENCE

Adrees, M., Ali, S., Rizwan, M., Ibrahim, M., Abbas, F., Farid, M., Zia-ur- Rehman, M., Irshad, M.K., Bharwana, S.A. 2015: The effect of excess copper on growth and physiology of important food crops: A review. Environ. Sci. Pollut. Res., 22, 8148–8162. [CrossRef].

Agarwala, S.C., Sharma, C.P. 1979: Plant nutrients - their functions and uptake. In: Soil Fertility - Theory and Practice (Ed.: J.S. Kanwar). I.C.A.R., New Delhi. pp. 7-64.

Alengebawy, A., Abdelkhalek, S.T., Qureshi, S.R., Wang, M.Q. 2021: Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. Toxics, 9(3), 42.

Ashraf, U., Kanu, A.S., Mo, Z.W., Hussain, S., Anjum, S.A., Khan, I., 2015: Lead toxicity in rice; effects, mechanisms and mitigation strategies-a mini review. *Environ. Sci. Pollut. Res.* 22, 18318–18332. doi: 10.1007/s11356-015-5463-x .

Ashraf, U., Kanu, A.S., Deng, Q., Mo, Z., Pan, S., Tian, H., Tang, X. 2017: Lead (Pb) toxicity; physio-biochemical mechanisms, grain yield, quality, and Pb distribution proportions in scented rice. Front. Plant Sci., 8, 259. [CrossRef] [PubMed].

Chauhan, P., Rajguru, A.B., Dudhe, M.Y., Mathur, J. 2020: Efficacy of lead (Pb) phytoextraction of five varieties of *Helianthus annuus L.* from contaminated soil. Environ. Technol. Innov., 18, 100718. [CrossRef].

Chiou, W.Y., Hsu, F.C. 2019: Copper toxicity and prediction models of copper content in leafy vegetables. Sustainability, 11, 6215. [CrossRef]

Day, A., Weber, E. 1981: Agricultural Potential for Municipal Wastewater in a Semiarid Environment. Journal of the Arizona-Nevada Academy of Science: 85–87.

Diaconu, M., Pavel, L.V., Hlihor, R.M., Rosca, M., Fertu, D.I., Lenz, M., Corvini, P.X., Gavrilescu, M., 2020: Characterization of heavy metal toxicity in some plants and microorganisms—A preliminary approach for environmental bioremediation. N. Biotechnol. 56, 130–139. [CrossRef] [PubMed].

Ghani, A., Naheed, S. 2011: Toxic effect of copper on growth, yield, photosynthetic pigments and mineral composition of wheat plants (Triticum aestivum L.). Pak. J. Chem, 1, 96-99.

Gupta, N., Yadav, K.K., Kumar, V.,Kumar, S., Chadd, R.P., Kumar, A. 2019: Trace elements in soil-vegetables interface: Translocation, bioaccumulation, toxicity and amelioration - A review. Sci. Total Environ., 651, 2927–2942. [CrossRef] [PubMed].

Kirmani, H.F., Hussain, M., Ahmad, F., Shahid, M., Asghar, A. 2018: Impact of zinc uptake on morphology, physiology and yield attributes of wheat in Pakistan, Cercetari Agronomic ˆın Moldova, , 51, 29–36.

He, J., Ren, Y., Chen, X., Chen, H. 2014: Protective roles of nitric oxide on seed germination and seedling growth of rice (*Oryza sativa* L.) under cadmium stress. Ecotoxicol. Environ. Saf., 108, 114–119. [CrossRef] .

Jamali, M.K., Kazi, T.G., Arain, M.B., Afridi, H.I., Jalbani, N., Kandhro, G.A., Baig, J.A. 2009: Heavy metal accumulation in different varieties of wheat (*Triticum aestivum L.*) grown in soil amended with domestic sewage sludge. *Journal of hazardous materials*, *164*(2-3), 1386-1391.

Jibril, S.A., Hassan, S.A., Ishak, C.F., Megat Wahab, P.E. 2017. Cadmium Toxicity Affects Phytochemicals and Nutrient Elements Composition of Lettuce (*Lactuca sativa* L.). Adv. Agric., 2017, 1–7. [CrossRef].

Kumar, A., Prasad, M.N.V., Sytar, O. 2012: Lead toxicity, defense strategies and associated indicative biomarkers in Talinum triangulare grown hydroponically. Chemosphere 89, 1056 – 1065. Doi: 10.1016/ j.chemosphere. 2012.05.070

Liang, J., Yang, W. 2019: Effects of Zinc and Copper Stress on Antioxidant System of Olive Leaves. IOP Conf. Ser. Earth Environ. Sci., 300, 52058. [CrossRef].

Luskin, B., Račaitė, M. 2008: Accumulation of Heavy Metals in Spring Wheat (*Triticum Aestivum L.*) Oveground and Underground Parts. *Environmental Research, Engineering & Management*, *46*(4).

Mahmood, T., Islam, K.R., Muhammad, S. 2007: Toxic effects of heavy metals on early growth and tolerance of cereal crops. *Pakistan journal of botany*, *39*(2), 451.

Mussarat, M., Jamal, W.A., Muhammad, D., Ahmad, M., Saleem, A., Khan, S., Malik, W. 2021**:** Risk of heavy metals accumulation in soil and wheat grains with waste water irrigation under different NPK levels in alkaline calcareous soil. PLoS One, 16(11), e0258724.

Sindhu, P., Saharma, A., Pooja, P. 2015: Total chlorophyll and total protein content in wheat (Triticum aestivum) grown under arsenic stress, Int. J. Recent Sci. Res., 6, 5072– 5075.

Pourrut, B., Shahid, M., Camille, D., Peter, W., Eric, P. 2011: Lead uptake, toxicity, and detoxification in plants. *Rev. Environ. Contam. Toxicol.* 213, 113–136. doi: 10.1007/978-1-4419-9860-6_4.

Riyazuddin, R., Nisha, N., Ejaz, B., Khan, M.I.R., Kumar, M., Ramteke, P.W., Gupta, R. 2021: A comprehensive review on the heavy metal toxicity and sequestration in plants. *Biomolecules*, *12*(1), 43.

Staniˇsi´c Stoji´c, S.M., Ignjatovi´c, L.M., Popov, S., ˇSkrivanj, S., ĐorCevi´c, A.R.,Stoji´c, A. 2016. Heavy metal accumulation in wheat and barley: the effects of soil presence and liquid manure amendment, Plant Biosyst., 150, 104–110.

Saifullah, A., Javed, H., Naeem, A., Rengel, Z., Dahlawi, S. 2016. Timing of foliar Zn application plays a vital role in minimizing Cd accumulation in wheat. Environ. Sci. Pollut. Res. Int., 23, 16432–16439. [CrossRef].

Schützendübel, A., Nikolova, P., Rudolf, C., Polle, A**.** 2002: Cadmium and H2O2-induced oxidative stress in Populus x canescens roots.Plant Physiol. Biochem., 40, 577–584. [CrossRef]

Shahid, M., Pinelli, E., Pourrut, B., Silvestre, J., Dumat, C. 2011: Lead-induced genotoxicity to Vicia faba L. roots in relation with metal cell uptake and initial speciation. Ecotoxicol. Environ. Saf. 74, 78–84. doi: 10.1016/j.ecoenv.2010.08.037

Sharma, D.C., Sharma, C.P. 1993: Chromium uptake and its effects on growth and biological yield of wheat. Cereal Res. Commun., 21, 317–322.

Sharma, P., Dubey, R.S. 2005: Lead toxicity in plants. *Braz. J. Plant Physiol.* 17, 35–52. doi: 10.1590/S1677-04202005000100004

Si-ping, L.I., Lu-sheng, Z.E.N.G., Zhong-liang, S.U. 2022: Wheat growth, photosynthesis and physiological characteristics under different soil Zn levels, Journal of Integrative Agriculture, Volume 21, Issue 7,Pages 1927-1940,ISSN 2095-3119,https://doi.org/10.1016/S2095-3119(21)63643-2. (https://www.sciencedirect.com/science/article/pii/S2095311921636432) .

Stolt, P., Asp, H., Hultin, S. 2006: Genetic variation in wheat cadmium accumulation on soils with different cadmium concentrations. J. Agron. Crop. Sci., 192, 201–208. [CrossRef].

Wuana, R.A., Okieimen, F.E. 2011: Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. ISRN Ecol., 2011, 1–20. [CrossRef] .

Table 1: The effects of Cd. Treatment(T) on wheat varieties on total height (T.H/ 85D) * and (T.H /115D) ** cm.

Variety	Cd. Conc. (T/ ppm)	T.H/ 85D	T.H/ 115D
Beni Suef 5	Control	62.2	68.3
	Cd_1 (0.01)	69.2**	87.3**
	Cd_2 (0.05)	67.1**	77.3**
	Cd_3 (0.1)	67.6**	87.6**
Beni Suef 6	Control	60.3	67.3
	Cd_1 (0.01)	61.3^{ns}	78.6**
	Cd_2 (0.05)	66.0**	74.5**
	Cd_3 (0.1)	67.0**	78.3**
Gemmayzeh 12	Control	62.3	73.0
	Cd_1 (0.01)	64.5**	76.3**
	Cd_2 (0.05)	65.0**	75.3**
	Cd_3 (0.1)	68.6**	78.3**
Sakha 94	Control	67.3	79.3
	Cd_1 (0.01)	68.0^{ns}	84.6**
	Cd_2 (0.05)	72.0**	81.6**
	Cd_3 (0.1)	70.7**	86.0**
Misr 1	Control	68.6	76.6
	Cd_1 (0.01)	70.6*	74.6*
	Cd_2 (0.05)	68.3^{ns}	75.6^{ns}
	Cd_3 (0.1)	70.8**	77.0^{ns}

Table 2: The effects of Zn. Treatment(T) on wheat varieties on total height (T.H/ 85D) * and (T.H /115D) ** cm.

Variety	Zn. Conc. (T/ ppm)	T.H/ 85D	T.H/ 115D
Beni Suef 5	Control	62.2	68.3
	Zn_1 (5.0)	68.3**	82.3**
	Zn_2 (10.0)	65.3**	73.0**
	Zn_3 (15.0)	64.3**	76.7**
Beni Suef 6	Control	60.3	67.3
	Zn_1 (5.0)	68.3**	73.0**
	Zn_2 (10.0)	64.7**	77.6**
	Zn_3 (15.0)	62.3**	74.3**
Gemmayzeh 12	Control	62.3	73.0
	Zn_1 (5.0)	67.7 **	72.0ns
	Zn_2 (10.0)	66.5**	69.3**
	Zn_3 (15.0)	64.0**	65.3**
Sakha 94	Control	67.3	79.3
	Z_{n1} (5.0)	71.6**	86.0 **
	Zn_2 (10.0)	69.3**	83.0**
	Zn_3 (15.0)	65.4**	82.6**
Misr 1	Control	68.6	76.6
	Zn_1 (5.0)	71.6**	77.0ns
	Zn_2 (10.0)	70.3*	76.7ns
	Zn_3 (15.0)	67.3ns	76.3ns

Table 3: The effects of Cu. Treatment (T) on wheat varieties on total height (**T.H/ 85D**) * and (**T.H /115D**) ** cm.

Variety	Cu. Conc. (T/ ppm)	T.H/ 85D	T.H/ 115D
Beni Suef 5	Control	62.2	68.3
	Cu_1 (5.0)	66.6**	76.0**
	Cu_2 (10.0)	68.6**	79.3**
	Cu_3 (15.0)	67.3**	78.3**
Beni Suef 6	Control	60.3	67.3
	Cu_1 (5.0)	62.6**	73.0**
	Cu_2 (10.0)	64.0**	76.6**
	Cu_3 (15.0)	65.6**	73.3**
Gemmayzeh 12	Control	62.3	73.0
	Cu_1 (5.0)	65.0 **	75.6**
	Cu_2 (10.0)	62.0ns	66.0**
	Cu_3 (15.0)	66.0**	78.0**
Sakha 94	Control	67.3	79.3
	Cu_1 (5.0)	65.3*	87.0 **
	Cu_2 (10.0)	71.0**	86.0**
	Cu_3 (15.0)	69.3**	83.3**
Misr 1	Control	68.6	76.6
	Cu_1 (5.0)	68.0ns	76.6ns
	Cu_2 (10.0)	68.3ns	72.6**
	Cu_3 (15.0)	69.3ns	81.0 **

Table 4: The effects of Pb. Treatments (T) on wheat varieties on total height (**T.H/ 85D**) * and (**T.H /115D**) ** cm.

Variety	Pb. Conc. (T/ ppm)	T.H/ 85D	T.H/ 115D
Beni Suef 5	Control	62.2	68.3
	Pb_1 (5.0)	67.3**	80.0**
	Pb_2 (10.0)	68.0**	82.6**
	Pb_3 (15.0)	66.3**	92.6**
Beni Suef 6	Control	60.3	67.3
	Pb_1 (5.0)	66.0**	70.0**
	Pb_2 (10.0)	64.5**	70.3**
	Pb_3 (15.0)	65.3**	84.3**
Gemmayzeh 12	Control	62.3	73.0
	Pb_1 (5.0)	65.5 **	75.6**
	Pb_2 (10.0)	66.3**	74.3ns
	Pb_3 (15.0)	65.6**	102.3**
Sakha 94	Control	67.3	79.3
	Pb_1 (5.0)	67.0ns	85.3 **
	Pb_2 (10.0)	68.0ns	82.6**
	Pb_3 (15.0)	67.0ns	84.3**
Misr 1	Control	68.6	76.6
	Pb_1 (5.0)	65.3**	77.3ns
	Pb_2 (10.0)	70.3*	76.6nn
	Pb_3 (15.0)	67.5ns	82.0 **

Table 5: The effects of Cd. Treatments (T) on some yield characteristics of wheat varieties [total weight (T.w), spike weight (Sp. w) and 100 grains weight (100 G.w)] per gm.

Variety	Cd. Conc. (T/ ppm)	T.w	Sp.w	100 G.w
Beni Suef 5	Control	2.3	0.6	3.4
	Cd_1 (0.01)	2.8^{**}	0.8^{**}	3.2^{ns}
	Cd_2 (0.05)	3.1^{**}	0.8^{**}	4.1^{**}
	Cd_3 (0.1)	2.8^{**}	0.9^{**}	4.5^{**}
Beni Suef 6	Control	1.3	0.5	3.9
	Cd_1 (0.01)	1.7^{**}	0.6^{ns}	4.5^{**}
	Cd_2 (0.05)	1.6^{**}	0.5^{ns}	5.1^{**}
	Cd_3 (0.1)	1.7^{**}	0.6^{ns}	5.4^{**}
Gemmayzeh 12	Control	2.1	0.6	3.7
	Cd_1 (0.01)	2.4^{*}	1.1^{**}	3.8^{ns}
	Cd_2 (0.05)	2.4^{*}	0.8^{**}	3.9^{*}
	Cd_3 (0.1)	2.4^{*}	0.9^{**}	4.3^{**}
Sakh94	Control	3.4	1.0	3.2
	Cd_1 (0.01)	3.3^{ns}	1.0^{ns}	3.3^{ns}
	Cd_2 (0.05)	3.2^{ns}	1.0^{ns}	3.2^{ns}
	Cd_3 (0.1)	2.8^{**}	1.0^{ns}	4.4^{**}
Misr 1	Control	3.2	0.9	3.7
	Cd_1 (0.01)	3.3^{ns}	1.1^{*}	3.0^{**}
	Cd_2 (0.05)	3.2^{ns}	1.0^{ns}	3.2^{**}
	Cd_3 (0.1)	3.2^{ns}	0.9^{ns}	3.2^{**}

Table 6: The effects of Zn. treatment(T) on some yield characteristics of wheat varieties [total weight (T.w) and spike weight (Sp. w) and 100 grains weight (100 G.w)] per gm.

Variety	Zn. Conc. (T/ ppm)	T.w	Sp.w	100 G.w
Beni Suef 5	Control	2.3	0.6	3.4
	Zn_1 (5.0)	2.2^{nn}	0.7^{ns}	4.4^{**}
	Zn_2 (10.0)	2.5^{nn}	0.7^{ns}	4.1^{**}
	Zn_3 (15.0)	1.6^{**}	0.6^{ns}	2.7^{**}
Beni Suef 6	Control	1.3	0.5	3.9
	Zn_1 (5.0)	2.2^{ns}	0.5^{ns}	4.7^{**}
	Zn_2 (10.0)	2.5^{ns}	0.4^{ns}	5.2^{**}
	Zn_3 (15.0)	1.3^{ns}	0.3^{**}	4.7^{**}
Gemmayzeh 12	Control	2.1	0.6	3.7
	Zn_1 (5.0)	1.7^{**}	0.7^{nn}	4.0^{ns}
	Zn_2 (10.0)	2.9^{**}	1.2^{**}	3.7^{**}
	Zn_3 (15.0)	1.6^{**}	0.8^{**}	3.2^{**}
Sakha 94	Control	3.4	1.0	3.2
	Zn_1 (5.0)	2.2^{**}	1.0^{ns}	4.0^{**}
	Zn_2 (10.0)	2.6^{**}	1.0^{ns}	2.7^{**}
	Zn_3 (15.0)	2.6^{**}	0.9^{ns}	2.7^{**}
Misr 1	Control	3.2	0.9	3.7
	Zn_1 (5.0)	2.7^{**}	0.9^{ns}	4.0^{ns}
	Zn_2 (10.0)	2.5^{**}	1.0^{ns}	3.4^{ns}
	Zn_3 (15.0)	1.9^{**}	0.8^{ns}	3.3^{**}

Table 7: The effects of Cu. treatment(T) on crop characteristics of wheat varieties [(total weight (T.w) and spike weight (Sp. w) and 100 grains weight (100 G.w)] per gm.

Variety	Cu. Conc. (T/ ppm)	T.w	Sp.w	100 G.w
Beni Suef 5	Control	2.3	0.6	3.4
	Cu_1 (5.0)	1.4^{**}	0.7^{ns}	3.4^{ns}
	Cu_2 (10.0)	2.8^{**}	0.6^{ns}	4.0^{**}
	Cu_3 (15.0)	1.9^{**}	0.7^{ns}	4.0^{**}
Beni Suef 6	Control	1.3	0.5	3.9
	Cu_1 (5.0)	1.2^{ns}	0.4^{ns}	4.9^{**}
	Cu_2 (10.0)	1.2^{ns}	0.5^{ns}	4.7^{**}
	Cu_3 (15.0)	1.4^{ns}	0.5^{ns}	5.2^{**}
Gemmayzeh 12	Control	2.1	0.6	3.7
	Cu_1 (5.0)	2.0^{ns}	0.8^{**}	2.8^{**}
	Cu_2 (10.0)	2.1^{ns}	0.8^{**}	3.6^{nn}
	Cu_3 (15.0)	1.8^{*}	0.6^{ns}	3.6^{nn}
Sakha 94	Control	3.4	1.0	3.2
	Cu_1 (5.0)	3.7^{ns}	0.9^{ns}	3.2^{ns}
	Cu_2 (10.0)	2.4^{**}	0.9^{ns}	3.8^{**}
	Cu_3 (15.0)	2.6^{**}	1.1^{ns}	4.3^{**}
Misr 1	Control	3.2	0.9	3.7
	Cu_1 (5.0)	3.5^{ns}	1.1^{*}	3.5^{ns}
	Cu_2 (10.0)	3.1^{ns}	1.1^{*}	3.6^{ns}
	Cu_3 (15.0)	2.9^{ns}	1.0^{ns}	4.0^{ns}

Table 8: The effects of Pb. Treatment (T) on crop characteristics of wheat varieties [(total weight (T.w) and spike weight (Sp. w) and 100 grains weight (100 G.w)] per gm.

Variety	Pb. Conc. (T/ ppm)	T.w	Sp.w	100 G.w
Beni Suef 5	Control	2.3	0.6	3.4
	Pb_1 (5.0)	2.0^{**}	0.8^{**}	4.2^{**}
	Pb_2 (10.0)	2.5^{**}	0.8^{**}	4.7^{**}
	Pb_3 (15.0)	3.1^{**}	0.8^{**}	4.8^{**}
Beni Suef 6	Control	1.3	0.5	3.9
	Pb_1 (5.0)	1.5^{nn}	0.5^{ns}	5.2^{**}
	Pb_2 (10.0)	1.7^{**}	0.6^{ns}	5.3^{**}
	Pb_3 (15.0)	1.3^{nn}	0.4^{ns}	5.2^{**}
Gemmayzeh 12	Control	2.1	0.6	3.7
	Pb_1 (5.0)	2.4^{**}	0.8^{**}	4.0^{ns}
	Pb_2 (10.0)	2.7^{**}	1.0^{**}	4.2^{**}
	Pb_3 (15.0)	2.5^{**}	1.1^{**}	4.8^{**}
Sakha 94	Control	3.4	1.0	3.2
	Pb_1 (5.0)	2.9^{**}	0.9^{ns}	3.6^{*}
	Pb_2 (10.0)	2.6^{**}	0.8^{*}	4.0^{**}
	Pb_3 (15.0)	2.8^{**}	0.8^{*}	4.6^{**}
Misr 1	Control	3.2	0.9	3.7
	Pb_1 (5.0)	3.3^{ns}	1.1^{*}	4.4^{**}
	Pb_2 (10.0)	3.2^{ns}	1.2^{**}	4.8^{**}
	Pb_3 (15.0)	2.8^{*}	1.1^{*}	4.3^{**}

السمية النباتية لبعض العناصر الثقيلة من خلال خمسة تراكيب وراثية مختلفة من القمح

مروى مبروك الفخراني [1,*]، عبدالهادي إبراهيم حسن سيد [2]، رانيا أحمد رشاد السعيد [1]، فتحية سعيد العناني [1]، رجب إبراهيم الخولي [2]

[1] قسم العلوم البيولوجية والبيئية، كلية الاقتصاد المنزلي، جامعة الأزهر، طنطا، مصر

[2] قسم النبات الزراعي (الوراثة) ،كلية الزراعة ، جامعة الأزهر, القاهرة 11884، مصر

* البريد الإلكتروني للباحث الرئيسي:.*marwaelfakharany290@azhar.edu.eg*

الملخص العربي

يحتوى القمح السداسي على 42 كروموسوم بينما يحتوي القمح الرباعي على 28 كروموسوم ويتأثر السلوك الكروموسومي بالمعاملة بالمعادن الثقيلة وتسبب المعاملة بالمعادن الثقيلة وجود كروموسومات غير عادية وتقلل المعاملة بالمعادن الثقيلة النسبة التنفسية والعمليات البنائية الحيوية. تعتبر السمية النباتية للمعادن الثقيلة المنبعثة من خلال الأنشطة البشرية سببا في انخفاض كبير في نمو المحاصيل وإنتاجيتها. أجريت الدراسة الحالية لتقييم تأثير بعض المعادن الثقيلة ؛ تأثير الكادميوم (Cd) والزنك (Zn) والنحاس (Cu) والرصاص (Pb) على نمو خمسة تراكيب وراثية مختلفة من القمح في مراحل مختلفة تحت الظروف الحقلية. أظهرت النتائج أن العناصر الثقيلة لها تأثير معنوي في بعض صفات النمو وبعض الصفات المحصولية. وكان للكادميوم أقل تأثير معنوي في صفات النبات يليه الزنك ثم النحاس والرصاص. تباينت الأنماط الجينية للقمح في استجابتها لإجهاد المعادن الثقيلة. علاوة على ذلك، يمكن أن نستنتج أن النمط الوراثي للقمح بني سويف 5 كان أعلى مقدره على التحمل ضد المعادن يليه الجميزة 12 وبني سويف 6، بينما أظهر سخا 94 ومصر 1 أقل مقدرة على تحمل تأثيرالمعادن. يمكن استخدام الأنماط الجينية المتحملة في مراحل النمو المختلفة تجارياً تحت إجهاد المعادن الثقيلة وكذلك يمكن استخدامها كأصناف مساعدة فى استحداث أصناف واعدة مخصصة للإنتاج الزراعي تحت إجهاد المعادن الثقيلة. وعلي وجه العموم اعطت النباتات الرباعية تاثيرا أقل خطورة من النباتات السداسية في استجابتها للمعادن الثقيلة وتراكمها داخل الخلايا, بينما الرصاص اعطي تأثيرًا إيجابيًا في تركيزاتة المنخفضة من حيث انتاجية النبات.

الكلمات الاسترشادية: Triticum aestivum L , الكادميوم , الزنك , النحاس , الرصاص.