SUMMARY

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Control of pollution with heavy metals in lettuce plants was investigated in two types of experiments i.e., pot experiments (three experiments) conducted at Desert Research Center (DRC), El-Mattaria, Cairo and a field experiment at El-Hana farm , El-Bostan extension area, El-Behaira governorate. Both types of experiments were conducted during two successive winter seasons of 1994/95 and 1995/96 to throw light on the effect of adding soil amendments i.e., organic manure, clay and calcium carbonate on the heavy metal toxic action in two lettuce (*Lactuca sativa*) cultivars namely: Balady and Great Lakes.

Thus, the study included four experiments as follows:

- The first experiment (Control of pollution with cadmium in lettuce plants grown in pots) This experiment included 32 treatments {(2 lettuce cultivars x 4 Cd levels of soil (0, 10, 20 and 30 ppm) x 4 soil amendments (0, 15 g organic manure, 10 g clay and 5 g $CaCO_3$ /kg soil)}.
- The second experiment (Control of pollution with nickel in lettuce plants grown in pots) This experiment included 32 treatments {(2 lettuce cultivars x 4 Ni levels of soil (0, 50, 100 and 150 ppm) x 4 soil amendments (0, organic manure, clay and $CaCO_3$ at the same amounts of the first experiment)}.
- The third experiment (Control of pollution with lead in lettuce plants grown in pots): This experiment included 32 treatments {(2 lettuce cultivars x 4 Pb levels of soil (0, 100, 200 and 300 ppm) x 4 soil amendments (0, organic manure, clay and $CaCO_3$ at the same amounts of the first experiment)}.

Each of the three pot experiments was designed as a complete randomized block pattern (2 lettuce cvs. X 4 soil amendments X 4 pollution source levels concerned in each experiment).

Both heavy metal species and amendment treatments at the levels mentioned above were thoroughly mixed with the used soil and the pots were

filled with the mixture before cultivation. Then, lettuce seedlings (one seedling in each pot) were transplanted on November 20th. and 25th. in 1994/95 and 1995/96 growing seasons, respectively.

- Field experiment (Control of pollution with sewage sludge borne heavy metals in lettuce plants): This experiment included 32 treatments {(2 lettuce cultivars x 4 sludge rates (0, 15, 30 and 45 ton/fad) x 4 soil amendments (0, 15 ton organic manure, 10 ton clay and 5 ton $CaCO_3$/fad)}.

The experiment was carried out as split- split plot design with three replicates. The two lettuce cultivars i.e., Balady and Great Lakes were arranged in the main plots, the four rates of sewage sludge were randomly situated in the sub-plots and the four amendment treatments were randomly distributed in the sub-sub plots .

In both growing winter seasons of 1994/95 and 1995/96; both sludge and soil amendment treatments were applied before transplanting. Lettuce seedlings were transplanted on November 15th. and 20th. in 1994/95 and 1995/96 growing seasons, respectively.

Obtained results can be summarized as follows:

A- **Plant growth characters and yield:**

1. Plants of Balady cultivar showed higher values of most of studied growth characters i.e., plant height, fresh and dry weights of both shoot and root and shoot/root as well as yield/fad (field experiment) than those of Great Lakes cultivar. However, number of leaves/plant was nonsignificantly affected.
2. Increasing any of the heavy metals (Cd, Ni and Pb) added to soil significantly and negatively affected plant growth. Whileas, increasing sludge rate application stimulated plant growth and yield with an insignificant difference between yields of 30 and 45 ton sludge/fad treatments.

3. Soil amendments application showed a significant and positive effect on plant growth and yield. The magnitude of effect followed the descending order: $CaCO_3 \geq$ clay > organic manure.
4. The combined treatment of zero level heavy metals + 5g $CaCO_3$ /kg soil application of Balady cultivar showed the highest values of growth parameters. Whileas, adding of 45 ton sludge/fad. + 10 ton clay or 5 ton $CaCO_3$ /fad of Balady cultivar gave the highest yield/fad.

B. Nutrients content :

1. Plant leaves of Great Lakes cultivar contained higher concentrations of macronutrients studied than those of Balady cultivar and vice versa in case of micronutrients.
2. Increasing the heavy metal level of soil led to a decrease in nutrients content of plant leaves. The opposite trend was obtained in case of sludge application rate, whereby increasing the sludge rate up to 45 ton/fad. increased the plant leaves content of nutrients.
3. Soil amendments differed widely in its effect on nutrients content of lettuce leaves. Organic manure treatment showed a pronounced effect on increasing micronutrients content of leaves, while clay treatment preceded the others in its effect on N, P, K and Mg content of leaves, whereas calcium carbonate gave the highest values of Ca of leaves, but it showed the opposite trend in case of micronutrients content.
4. The highest values of N, P, K and Mg content of lettuce leaves were obtained with the combined treatment of Great Lakes cultivar + the low level of heavy metal added to soil (10, 50 and 100 ppm for Cd, Ni, and Pb, respectively) + Clay or organic manure.

   In case of sludge application at the rate of 30 ton/fad. + 5 ton $CaCO_3$ /fad, Great Lakes cultivar showed the highest values of macronutrient content of leaves, while (15 ton sludge + zero amendment application + Balady cultivar) treatment led to the highest values of micronutrient content of leaves.

C. Heavy metal content :

1. Plant leaves of Balady cultivar contained less amounts of heavy metals i.e., Cd, Ni and Pb, especially in case of the highest level of pollution under this study compared with those of Great Lakes.
2. Increasing Cd applied rate to the soil gradually increased its concentration in plant leaves, meanwhile an antagonistic effect on the concentration of either Ni or Pb in this respect could be detected. Increasing Ni applied rate to the soil progressively increased Cd as well as Ni concentration in plant leaves. However, contra trend was detected in case of lead concentration up till the medium Ni level (100 ppm) was applied. Meanwhile, the highest Ni level (150 ppm) induced an enrichment in lead accumulation in leaves over the control treatment.

   As for lead application to the soil, an increasing tendency in Cd concentration in leaves was detected, meanwhile Ni as well as Pb content of leaves was decreased, especially when low or medium lead levels (100 or 200 ppm) were applied. However, the highest lead level (300 ppm) again increased the concentration of both Ni and Pb over the control treatment.

   With regard to sewage sludge treatments, it was found that increasing rates up to 45 ton /fad led to a gradual and consistent increase in each of Cd, Ni and Pb content in plant leaves.
3. Soil amendment application showed mostly a favourable effect on reducing the deleterious action of heavy metal i.e., Cd, Ni and Pb in plant organs through affecting its availability to plant uptake. This held true either in pots or in field experiments under the condition of this study. The amendments efficiency had the order of descending magnitude $CaCO_3$ > clay > organic manure, which showed the least positive effect in this respect.
4. Application of soil amendments, especially $CaCO_3$ (5 ton/fad) to lettuce plants, especially Balady cultivar grown in soil supplemented with

sewage sludge borne heavy metals at any rate, especially up till 30 ton/fad led to an obvious minimizing effect on the accumulation of heavy metals studied in leaves.

D. Metabolic changes :

1. Plant leaves of Great Lakes cultivar contained generally higher concentration of ascorbic acid, NO_3 and total amino acids than those of Balady. The opposite was true with respect to photosynthetic pigments (chlorophyll a, b, total and carotene).
2. Increasing the level of heavy metals added to soil depressed the metabolic products determined except for: amino acids under all pollution sources studied, NO_3 under Ni pollution and carotene under Pb pollution as well as photosynthetic pigments under sludge treatment, whereby increasing the pollution load increased the metabolic products mentioned.
3. All soil amendments applied to soil contaminated either with each of heavy metals (pot experiment) or sewage sludge (field experiment) mostly increased all photosynthetic pigments (chlorophyll a, b and carotene) contents in plant leaves with special reference to clay treatment, which was of superior effect in this respect compared with the control treatment. Contra trend was detected in case of NO3, whereas all amendments led to a decreasing tendency with special reference to CaCO3, which showed superiority in this respect compared with other amendments used as well as control treatment. As for ascorbic acid content, no clear trend could be detected according to amendments used.
4. The interaction effect of factors studied varied widely due to experimental pollution species and variables tested. The most important factor in this respect was soil amendment application, especially clay or CaCO3 which had a favourable effect on increasing photosynthetic pigments and decreasing the NO3 accumulation in plant leaves of both cultivars and various pollution conditions. Ascorbic acid tended to be decreased with

the application of soil amendments in leaves of both cultivars grown under sludge amended soil.

Finally, it can be concluded that generally, heavy metals pollution caused depressive effects on plant growth and yield of lettuce plants as well as it induced hazardous effects on the accumulation of such heavy metals in leaves consumed by human. Furthermore, CaCO3 or clay as soil amendments can play an effective role in reducing absorption and accumulation of heavy metals investigated under the experiments condition. Plants of Balady cultivar absorbed and accumulated less amounts of heavy metals than those of Great Lakes cultivar, especially under high pollution levels of such metals. Though both organic manuring and sludge application enhanced the absorption and accumulation of heavy metals under the circumstance of this study, the later led to an increase in plant growth and yield.

Therefore, it is recommended that under heavy metal pollution condition or the application of sewage sludge to select species and cultivars that can tolerate the absorption and consequently the accumulation of such heavy metals in plant organs. For the beneficial effect of soil amendments such as CaCO3 and clay, the experimental work of this study recommended its application to sandy soils polluted with heavy metals and/or sludge amended.