# Effect of Liming on the Heavy Metal Uptake of Lettuce

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## Introduction

Toxic heavy metal contaminants reaching the environment are especially dangerous because they are capable of remaining hidden for a long time and of accumulating in the form of stable complexes or chelates. In many cases the accumulation process is very slow, and only causes damage after some decades or centuries (ALLOWAY, 1995).

Results of studies conducted from the 1960's have made it evident that, especially in industrial districts and towns, the heavy metal level may increase irregularly in the soil. Though heavy metal contents are not that high in various areas to be able to cause acute intoxication symptoms, their increased concentration in the food chain during a long period can provoke detectable health deterioration (ADRIANO, 1986).

Among heavy metals, cadmium is of great importance because it can have a toxic effect on plants, animals and human beings and it can accumulate in the human organism.

The extent of cadmium accumulation is to be taken into consideration, especially in case of plants which accumulate these heavy metals in their parts fit for consumption. Among vegetable crops, lettuce, beetroot and carrot accumulate large amounts of cadmium.

The availability of cadmium to plants is influenced by various soil factors, among them, according to literature data, soil reaction is of special importance (KÁDÁR, 1995). At lower soil pH higher quantities of Cd get into the soil solution in diluted form, thus the Cd uptake of plants increases (LEHOCZKY et al., 1996; CSILLAG et al., 1997). The Cd uptake of acid soils can be lowered with liming, therefore soil amelioration may become more important from the point of view of environment protection, too.

In Hungary an up-to-date agro-environment management programme was launched by working out the Soil Conservation Information and Monitoring System (TIM) as part of the Environment Protection Information and Moni-

toring System. The observation network was established and the actual detection started in 1992 at 1200 designated observation sites. Based on the data obtained from the analysis of soil samples taken from these sites, some of those were chosen where liming can be reasonable. The paper presents results of a study conducted with a soil taken from the surroundings of a TIM observation site.

The aim of the pot trials was to study the change in biomass production and heavy metal uptake of test plants as a consequence of liming. From the results related to heavy metal uptake, the ones concerning Mn and Zn, as essential elements, and Cd, as a toxic heavy metal, are reported in this paper.

Answers were sought to the following questions:

1. How does lime at different rates influence the soil pH and the solubility of heavy metals (Mn, Zn, Cd)?

2. How does liming with different rates affect the biomass production of lettuce?

3. What changes can be detected in the Cd content of the experimental plant under liming?

## Materials and Methods

Pot experiments were carried out under greenhouse conditions using an alluvial soil taken from the surroundings of a TIM site (Code No.: S4810 – environs of Gyöngyös).

Pots were filled with 6 kg air-dried soil. The main characteristics of the experimental soil were as follows: $pH_{KCl}$ = 6.3; $pH_{H2O}$ = 6.9; clay (<0.002) = 21.17%; silt (0.02-0.002) = 18.7%; T-value = 30.47 meq/100 g soil; S-value = 24.45 meq/100 g soil; hydrolytic acidity= 5.1.

The effect of liming was studied in the following treatments ($CaCO_3$ g/kg soil): control = 0, L 1 = 4.5, L 2 = 9.0, in five replicates.

Lettuce (*Lactuca sativa* L.) cv. Balatonzöld was the test plant (0.2 g seed/pot). Plants were grown for 28 days. Fresh and dry weights per pot were determined after harvest. The concentration of the given elements was determined by ICP mass spectrometry after digestion with concentrated nitric acid.

## Results

The heavy metal content of the experimental soil is shown in Table 1.

According to the obtained results there was a significant change in soil pH due to the applied liming rates, as compared to the control (Table 2).

No significant difference was found between the effect of the two liming rates.

*Table 1*
**Heavy metal content of the experimental soil (mg/kg soil)**

| | Total heavy metal content (cc. $HNO_3$) | Heavy metal content determined by the Lakanen-Erviö method |
|---|---|---|
| Mn | 1117.40 | 504.90 |
| Zn | 658.20 | 290.80 |
| Cd | 3.86 | 2.61 |

*Table 2*
**Effect of liming rates on the soil pH and on the concentration of available heavy metals (mg/kg soil)**

| Liming rates | $pH_{KCl}$ | $pH_{H2O}$ | Available heavy metal content* | | |
|---|---|---|---|---|---|
| | | | Mn | Zn | Cd |
| Control | 6.38 a | 6.94 a | 504.9 a | 290.8 a | 2.61 a |
| L 1 | 6.92 b | 7.23 b | 495.7 a | 278.4 a | 2.51 a |
| L 2 | 6.95 b | 7.27 b | 476.7 a | 285.8 a | 2.57 a |
| $LSD_{5\%}$ | 0.12 | 0.06 | 51.8 | 43.7 | 0.40 |

* determined by the Lakanen-Erviö method.
Liming rates: Control: 0, L1: 4.5, L2: 9.0 g $CaCO_3$/kg soil

There was no significant difference in the heavy metal content (determined by the Lakanen-Erviö (LE) method (1971)) between the lime-treated soils and the control.

Comparing these results with the total element content data (Table 1), it can be concluded that 42-45%, 42-44% and 64-67% of the total Mn, Zn and Cd content was determined in the LE extract, respectively, which is considered readily available for plants, according to literature data.

Results of studies on the biomass production and heavy metal contentration of lettuce plants are shown in Table 3.

The applied lime rates caused no mathematically confirmed changes in fresh and dry weights of lettuce plants as compared to the control. Mn, Zn and Cd concentrations of lettuce plants were lower in the limed soils than in the untreated one.

Among the elements involved in the experiment, the change in the Mn concentration was the most provoked by liming. Mn concentration of plants was 33% and 53% lower in treatments L1 and L2, respectively, as compared to the control. The double liming rate caused a further, significant decrease in Mn uptake in comparison to treatment L1. The Zn concentration showed considerably slighter changes, it was 12% and 18% lower in treatments L1 and L2,

*Table 3*

**Biomass production and heavy metal concentration of lettuce plants**

| Liming rates | Biomass weight, g/pot | | Mn | Zn | Cd | Mn | Zn | Cd |
|---|---|---|---|---|---|---|---|---|
| | Fresh | Dry | concentration, mg/kg dry matter | | | uptake by plants, µg/pot | | |
| Cont | 47.1 a | 2.64 a | 114.7 c | 182.7 b | 5.12 b | 300.2 c | 483.2 a | 13.5 b |
| L 1 | 50.8 a | 2.92 a | 77.1 b | 160.5 a | 3.14 a | 226.9 b | 471.0 a | 9.2 a |
| L 2 | 47.8 a | 2.77 a | 54.1 a | 148.6 a | 3.19 a | 150.4 a | 412.9 a | 8.9 a |
| $LSD_{5\%}$ | 6.35 | 0.35 | 19.5 | 15.06 | 0.69 | 55.9 | 86.8 | 2.4 |

respectively, than in the control. There was no mathematically confirmed difference between the effect of the two liming rates.

Cd concentration of plant leaves decreased considerably (by 38%) after liming, as compared to the control. There was no difference between the effect of the two liming rates, Cd concentration of plants did not decrease further with the application of the double liming rate.

The total quantity of Mn taken up by lettuce plants altered according to the concentration changes caused by the applied liming rates. The quantity of Zn taken up decreased, but the differences were not significant. The total amount of Cd uptake by plants was 32-34% less in the lime-treated soils.

Cd accumulation was observed in the leaves of lettuce plants grown on the untreated soil. Cadmium concentration in the dry matter of lettuce plants (Table 3) was twice as high as the available Cd content of the soil (Table 1). Comparing the Cd concentration of plants with the total quantity of Cd in the untreated soil, a 30% increase was found. These results confirm findings that lettuce can intensively accumulate Cd in leaves.

A negative linear correlation was found between the soil pH ($pH_{KCl}$) and Cd concentration of lettuce, which can be described with the following function: $y = 25.94–3.28x$; $r = -0.8681$; $r^2 = 75.36$; $n = 15$; $P < 0.001$.

## Conclusions

In the pot experiment, treatment with 4.5 g $CaCO_3$/kg soil caused a mathematically confirmed change in the soil pH, the effect of the double lime rate was not confirmed. Mn, Zn and Cd concentrations in the leaves of lettuce plants decreased after the liming treatment.

The double liming rate did not provoke a further decrease in Zn and Cd uptake of plants. Among the studied heavy metals, Zn uptake by plants decreased to the slightest degree.

The greatest changes due to the increase in soil pH caused by liming were observed in the Mn concentration of plants. The results confirm the fact known from literature data that soil pH is very important from the point of view of Mn mobility, of the increase of exchangeable and easily reducible Mn forms.

Former results also confirm that lettuce can intensively accumulate Cd in the leaves (LEHOCZKY et al., 1998).

It can be concluded from the results that liming greatly influenced the Cd uptake of lettuce plants. The cadmium concentration of plants decreased due to the change in soil pH.

In treatment L1 the Cd concentration of lettuce plants was 38% less than in the untreated control. No further decrease was detected in treatment L2. Similarly to the results obtained related to the effect on soil pH, no mathematically confirmed difference was found between the effect of the two liming rates.

The quantity of Cd taken up by lettuce on lime-treated soil was 30% less than in the control. A negative linear correlation was found between the soil $pH_{KCl}$ and Cd concentration of lettuce plants.

## Summary

Soil is the basic natural resource of food production. The heavy metal contamination of soils is of great importance from the ecological as well as public health point of view. One part of heavy metals belong to the essential elements important for plant life (e. g. Mn, Zn, Cu), while another part is not essential or even can be toxic (e. g. Cd, Ni, Pb) to both plants and animals.

High concentrations of toxic heavy metals rarely occur in soils under natural conditions. Soil contamination by toxic elements is generally the result of human activities.

The accumulation of heavy metals has a negative effect on the productivity and microbiological processes of soils, plant growth and development as well as on the quality of agricultural products.

Pot experiments were conducted under greenhouse conditions to study the effect of liming with growing rates. The objective of the experiment carried out on the alluvial soil contaminated by heavy metals was to study the effect of liming on the mobility of heavy metals (Mn, Zn, Cd) and on their uptake by the lettuce test plants.

Soil pH changed significantly due to the applied liming rates. Biomass production of lettuce plants was similar in the treated and untreated soils. Mn, Zn and Cd concentrations of the plants decreased as a consequence of liming, the greatest decrease was observed in case of Mn.

Cd accumulation was registered in leaves of lettuce plants grown on the untreated soil.

There was also a considerable decrease in the cadmium content of leaves in the liming treatments (38%), as compared to the control. The total quantity of

Cd taken up by lettuce in lime-treated soil was 30% less than in the control. A negative linear correlation was found between the soil pH ($pH_{KCl}$) and Cd concentration of lettuce plants.

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