

# The influence of environmental factors and heavy metals in the soil on plants' growth and development

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**Abstract:** Plants need certain conditions that represent their living environment. When the living environment provides the conditions required by the plant, it will grow and develop properly. The growth and development of plants involve environmental factors, which represent those constituent elements of the natural environment, which actively intervene in plants' life.

The present work shows the characteristics of an agricultural soil, contaminated with heavy metals (Cu, Pb and Zn) in different concentrations, which has been divided into pots, in which were thereafter planted vegetable seedlings (tomatoes, cucumbers, parsley, spinach, carrots, radishes). During the plants' growing time, the temperature and humidity of the air inside the greenhouse, as well as the humidity and pH of the soil, were monitored. The growth and the development of the plants under certain conditions were also tracked, until the end of the growing period. The results of monitoring the plants' growth and development are important in assessing the impact of the contamination over the soil and the plants.

**Key words:** environmental factors, heavy metals, soil, plants

## Introduction

The main environmental factors that influence plants' growth and development are: light, temperature, water, air (carbon dioxide and oxygen), nutrients, PH and toxic substances. In some situations, environmental factors may become restrictive for growth and development processes, as they become harmful if they exceed certain limits and values or they cannot meet the necessary plants' requirements. All environmental factors are relatively equal in the process of growth and development, the insufficiency of one having negative repercussions on plants.

Systemic toxic pollutants, such as heavy metals, are particularly dangerous due to their long-lasting remanence in the soil, as well as to their intake by the plants and, implicitly, by humans. The main routes of the collection of metals by plants are the radicular takeover and the foliar takeover.

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The **cucumber** (*Cucumis sativus*) is a vegetable plant, its optimum vegetation temperature is 25-28°C, and the average temperature should not fall below 15°C. The plants do not bear temperatures below 12°C or above 35°C, values outside of this range stopping the growth.

They are light-loving plants, needing 12 hours of light per day, prefer aerated soil, rich in humus, permeable, with neutral or low acid pH, with a humidity maintained at 70-80%.

The grown tomatoes come from the wild species of *Lycopersicon esculentum var. cerasiforme*, originated from the highlands of the Andes. They are annual plants that do not require special environmental conditions, in need of light and of a temperature that must not exceed 40°C nor be less than 10°C. Tomatoes prefer medium-sized sandy-clay, clay-sandy soils, rich in humus, fertile, well-structured, with a good, deep drainage, with deep groundwater and a PH level between 5.5 and 7.0, and humidity between 40 and 70%.

The **spinach** (*Spinacea oleracea*) is native in Central Asia; in Romania is cultivated in all areas. The spinach is a plant resistant to low temperatures, with the optimal growth temperature of 15-17°C. In terms of light, spinach is a less demanding species, which grows well in spring, autumn and winter, when the light radiation is low. Water plays an important role in obtaining a rich foil, being necessary that the soil moisture is constant. The spinach prefers loose, wet soils, rich in humus, with a pH of 6.5-7.5 [1].

The **parsley** (*Petroselinum crispum L*) is native in the Mediterranean Sea area since the beginning of our era and can be cultivated both for the root and the leaves. The minimum germination temperature is 2-4 °C, and the optimum vegetation temperature is 20°C. Plants can withstand temperatures of up to -30°C. The water requirements are moderate, being resistant to drought but it is a light-loving plant. In terms of soil requirements, it is a demanding plant, preferring loose, light, deep and well-fattened lands, the ideal being the clay-sandy ones.

The **carrot** (*Daucus carota L*) is not exigent to heat; its preferred temperature is between 15 and 24°C. Temperatures above 30°C are harder to tolerate, while the minimum temperature they endure is 3°C. It prefers as much light as possible: being a long day plant, the more light it receives, the more it will develop harmoniously; same thing happens in the case of humidity. For the carrot, the ideal soil should be clay-sandy, sandy, alluvial, with a pH between 5.8-7 [2].

The **radishes** (*Raphanus sativus L*) are cold-resistant plants, adapting to temperatures between 2 and 17°C. They are plants that need a lot of light and heat, and their favorite soils are those with light or medium texture, rich in humus, loosened, with a neutral pH and a good water retention capacity.

The plants capture and accumulate heavy metals, and this is due to certain factors such as: the climate, the concentrations of heavy metals within the soil, the nature of the soil in which they are grown, the atmosphere and the plants' maturity degree at their harvest [3,4,5].

The heavy metals can be grouped into essential and non-essential metals. The essential heavy metals are Co, Cr, Cu, Fe, Mn, Ni and Zn and are considered to be essential micronutrients, but they become poisonous when taken in excessive quantities. The non-essential heavy metals include Pb, Cd and Hg and are highly toxic to living organisms [6,7].

The long-term consumption of foods containing unsafe amounts of heavy metals can have repercussions on internal organs such as kidneys, liver, heart, and lead to various diseases over time such as chronic, kidney, cardiovascular, bone and nervous system diseases [8,9].

The main way of transferring the metals to the plant is by absorption through its roots.

The main routes of the collection of metals by plants are the radicular takeover and the foliar takeover. The environmental factors that make up the plants' living framework are: light, temperature, water, air and culture substrate. The temperature is one of the most important climatic factors that influence the growth and development rate of the plants. It conditions the unfolding of fundamental processes that take place in plants (growth, photosynthesis, respiration, transpiration, absorption of water and of nutritional salts, etc.). The vital processes of plants can only take place at certain temperatures [4,10]. The growth and development of plants depends on the temperature in the atmosphere. The main source of heat of the atmosphere is the solar energy, from which plants absorb only a fraction of it. Each plant species has specific thermal requirements which causes the temperature to have a limiting action on their growth and development [10].

The paper presents the monitoring of soil parameters, atmosphere and plants (vegetables) along a vegetation cycle.

## Material and method

The period of planting the vegetable seedlings was done between March and April 2018. Heavy metal infestation experiments carried out between March and September 2018 were done for a number of 7 plants (vegetables), specified in Table 1.

Table 1 - Classification of the vegetable plants studied [11]

| Group                     | Common name | Scientific name of the plant   |
|---------------------------|-------------|--------------------------------|
| Cucurbitaceous vegetables | Cucumber    | <i>Cucumis sativus</i> L       |
| Solano-fruit vegetables   | Tomatoes    | <i>Lycopersicon esculentum</i> |
|                           | Spinach     | <i>Spinacia oleracea</i> L     |
|                           | Parsley     | <i>Petroselinum crispum</i> L  |
| Root vegetables           | Carrot      | <i>Daucus carota</i> L         |
|                           | Parsley     | <i>Petroselinum crispum</i> L  |
|                           | Radishes    | <i>Raphanus sativus</i> L      |

The figure #1 shows aspects of the experimental research for the vegetable plants studied.

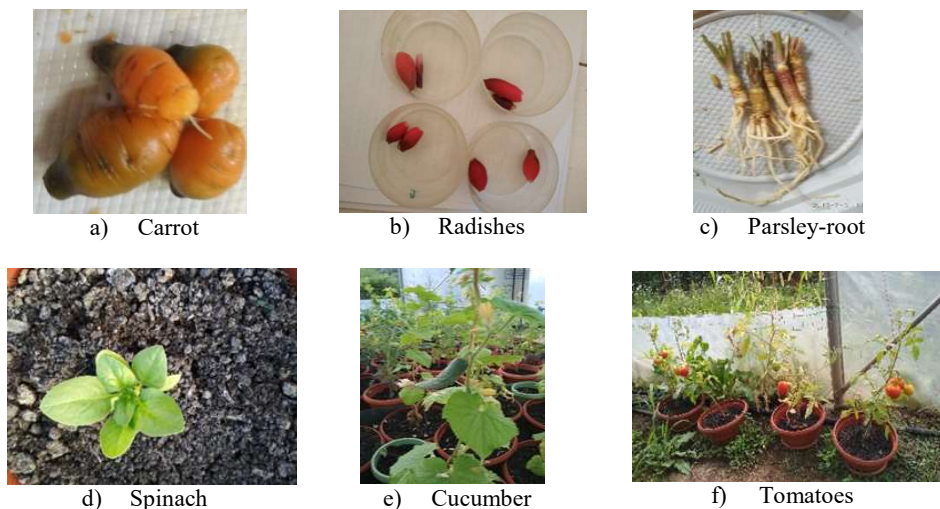


Fig. 1. - The stage of vegetable development.

All types of plants were planted in the soil and infested with the following four heavy metal concentrations: 1.5%, 3.0%, 4.5%, 6.0% and the heavy metals used were: copper, zinc, lead. In parallel, experiments were performed on plants grown in uninfested soil (0%).

The concentrations specified in the study for the study of metals were chosen taking into account the limits allowed for them, an experiment performed on salads grown on contaminated soils with different concentrations to see the behavior of plants, but also the literature in the field.

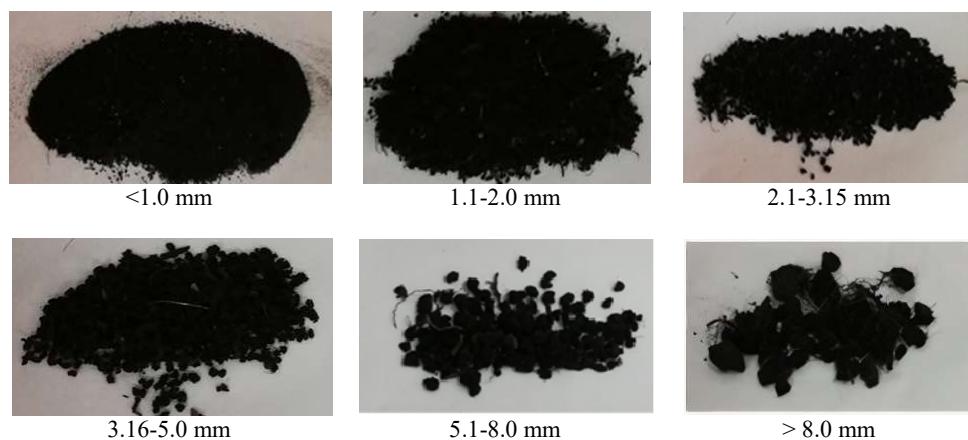
Of the metals chosen in the work, lead is the most dangerous metal, so care must be taken with its content in both soil and plant, as it can seriously disrupt human health. In the paper, it is observed that at concentrations of 3%, 4.5% and 6.0% Pb exceeds the permissible imitation in the soil which is 50 mg/kg.

In the experiments with vegetables the loading with heavy metal was carried out initially, when planting the seedlings, without supplementing it until the harvest.

The physico-chemical properties of the agricultural soil used in the experimental research were: pH 5.0-7.0, total nitrogen 1.9%, total phosphorus 0.5%, total potassium 0.9%, electrical conductivity 1.2, humidity 14.7.

The metals content of soils and plants was measured using a flame atomic absorption spectrometry

The granulometric analysis of the agricultural soil used in the experimental research was also carried out, the aspects during the work being shown in Figure 2 and the results obtained are shown in Figure 3.



**Fig. 2.** Aspects during the screening of the agricultural soil used for the experimental tests

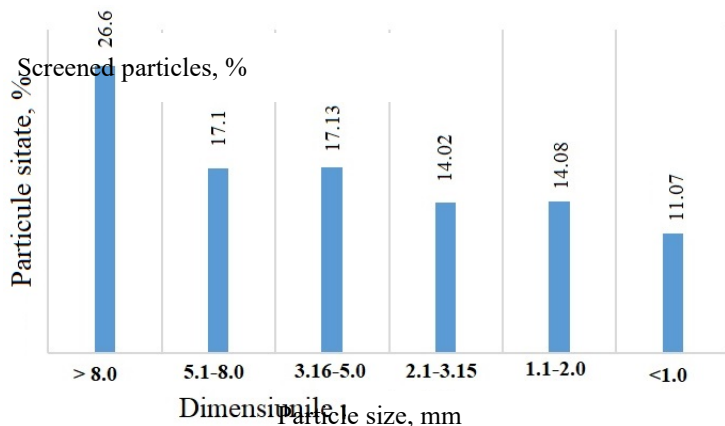
In the table 2 is presented the normal reference, alert threshold and intervention threshold values for soils of sensitive use listed in the Order no. 756/1997 of The Ministry of Waters, Forests and Environment Protection [12] and the maximum admitted values in leafy vegetables by FAO/OMS-Codex Alimentarius Commission, 2001 [13].

**Table 2 - Heavy metal content (Cu, Zn, Pb) in the soil/plant, mg·kg<sup>-1</sup>**

| Soil Types /Plant types                             | Cu   | Zn   | Pb  |
|---|------|------|-----|
| Normal values [12]                                  | 20   | 100  | 20  |
| Alert threshold [12]                                | 100  | 300  | 50  |
| Intervention threshold [12]                         | 200  | 600  | 100 |
| Maximum admissible values for leafy vegetables [13] | 73.3 | 99.4 | 0.3 |

## Results and discussions

Figure 3 showed the results obtained from the granulometric analysis of the agricultural soil used in the planting of vegetables.



**Fig. 3.** Granulometric analysis of soil used in experimental research

The soil parameters during the experimental research were: pH between 5.0-6.5 and soil moisture between 62.5-77.6%.

The atmospheric conditions in the greenhouse during the growth of plants were: temperatures between 18-30 °C and air humidity between 45-80 %.

The following tables show the tracking of the evolution of the plants, in the case of soils contaminated with the three metals, namely Cu (table 3), Pb (table 4), Zn (table 5).

**Table 3 - Plants subject to Cu infestation**

| Current no                       | Plant name     | Vegetation period, (days) | Harvest time (days) / Categories of concentrations (%) |      |       |       |       |
|----------------------------------|----------------|---------------------------|--|------|-------|-------|-------|
|                                  |                |                           | 0  | 1.5  | 3.0   | 4.5   | 6.0   |
| Quantity of metal in soil, mg/kg |                |                           | 17.6   | 58.9 | 267.2 | 525.1 | 680.8 |
| 1                                | Spinach        | 40-50                     | 45   | 45   | 45    | 45    | 45    |
| 2                                | Parsley (leaf) | 30-35                     | 33   | 33   | 33    | 33    | 33    |
| 3                                | Parsley (root) | 70-145                    | 74   | 74   | 74    | 74    | 74    |
| 4                                | Radishes       | 30                        | 30   | 30   | 30    | 30    | 30    |
| 5                                | Carrot         | 45                        | 45   | 45   | 45    | 45    | 45    |
| 6                                | Cucumber       | 38-50                     | 44   | 33   | 40    | 40    | 40    |
| 7                                | Tomatoes       | 90-130                    | 73   | 73   | -     | 93    | 80    |

**Table 4 - Plants subject to Pb infestation**

| Current no                       | Plant name     | Vegetation period, (days) | Harvest time (days) / Categories of concentrations (%) |      |      |       |       |
|----------------------------------|----------------|---------------------------|--|------|------|-------|-------|
|                                  |                |                           | 0  | 1.5  | 3.0  | 4.5   | 6.0   |
| Quantity of metal in soil, mg/kg |                |                           | 6.75   | 48.7 | 84.7 | 117.7 | 285.2 |
| 1                                | Spinach        | 40-50                     | 45   | 45   | 45   | 45    | 45    |
| 2                                | Parsley (leaf) | 30-35                     | 33   | 33   | 33   | 33    | 33    |

|   |                |        |    |     |    |    |    |
|---|----------------|--------|----|-----|----|----|----|
| 3 | Parsley (root) | 70-145 | 74 | 74  | 74 | 74 | 74 |
| 4 | Radishes       | 30     | 30 | 30  | 30 | 30 | 30 |
| 5 | Carrot         | 45     | 45 | 45  | 45 | 45 | 45 |
| 6 | Cucumber       | 38-50  | 44 | 26  | 40 | 40 | 26 |
| 7 | Tomatoes       | 90-130 | 73 | 106 | -  | 80 | 95 |

**Table 5** - Plants subject to Zn infestation

| Current no                              | Plant name     | Vegetation period, (days) | Harvest time (days) / Categories of concentrations (%) |       |       |       |        |
|---|----------------|---------------------------|--|-------|-------|-------|--------|
|   |                |                           | 0  | 1.5   | 3.0   | 4.5   | 6.0    |
| <b>Quantity of metal in soil, mg/kg</b> |                |                           | 39.8   | 202.7 | 534.8 | 921.7 | 1052.3 |
| 1                                       | Spinach        | 40-50                     | 45   | 45    | 45    | 45    | 45     |
| 2                                       | Parsley (leaf) | 30-35                     | 33   | 33    | 33    | 33    | 33     |
| 3                                       | Parsley (root) | 70-145                    | 74   | 74    | 74    | 74    | 74     |
| 4                                       | Radishes       | 30                        | 30   | 30    | 30    | 30    | 30     |
| 5                                       | Carrot         | 45                        | 45   | 45    | 45    | 45    | 45     |
| 6                                       | Cucumber       | 38-50                     | 44   | 26    | 40    | 26    | 29     |
| 7                                       | Tomatoes       | 90-130                    | 73   | 80    | 73    | 73    | 73     |

Considering all the cases of vegetables grown with various concentrations of heavy metal in the soil, it was observed:

- a tendency to increase the amount of heavy metal accumulated in the plant, along with the increase of the initial concentration of heavy metal in the soil.
- the curves of variation of the concentration of heavy metal in plants that are monotonously increasing, appeared more often in the case of infestations with lead and zinc (for carrots, parsley and spinach), and less with copper;
- the curves of variation of the concentration of heavy metal in oscillating plants, appeared more often in the case of infestations with copper, and less with lead and zinc;
- in radishes the curves were increasing for all three metals, while in tomatoes the curves were oscillating for all three metals;
- in cucumbers, the monotonous increasing curves appeared in the case of infestations with copper and zinc, and less with lead.

## Conclusions

Following the experiments on the seven plants we found that:

- All vegetables grown on uninfested soil (0%), agricultural soil, reached plant maturity and were harvested in the optimal period.
- The spinach, parsley, radishes and carrots have reached vegetable maturity and have been harvested in the optimal period, at the same interval for all metals and concentrations.
- Cucumbers failed to reach plant maturity and were harvested earlier in the case of soil contaminated with 1.5% concentration, with Pb concentration 1.5% and 6% and Zn of concentration 1.5%; 4.5% and 6%.
- Tomatoes were the most affected plants from the ones tested; out of them, only those contaminated with 4.5% and 6% concentration and those contaminated with Pb concentration 6% were the only ones that reached plant maturity, and those that were contaminated with 3% concentration and 3% concentration Pb, they were lost drying before harvesting.

From the above mentioned, we can find that plants that have a shorter period of vegetation have survived and developed better in contaminated soil than those that have a longer vegetation period.

The research presented in the paper is important both for growers and consumers of fresh vegetables alike, but also for researchers, as this can be a starting point for future research in the field of heavy metal soil contamination and of vegetables, implicitly.

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