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*Ecology*

# Bioaccumulation of Macro and Micro Elements by the *Amaranthus Viridis* from the Cadmium-Contaminated Soil

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**Green Amaranthus (*Amaranthus viridis*) is a common herb grown and eaten globally. We conducted a greenhouse experiment to determine Cd absorption by the Amaranthus, when the concentration of cadmium in the soil varies from 0.5 to 11 mg/kg. The plant Amaranthus absorbs more Cd, when the soil is contaminated with Cd in the concentration range from 1 mg/kg to 1.5 mg/kg. From 2.9 mg/kg to 11 mg/kg the plant absorbed cadmium concentration is low and does not exceed 1.6 mg/kg. During the study, it was identified that the concentration of Cd in the soil is in a regressive relationship with zinc – $R^2 = 0.47$, arsenic – $R^2 = 0.15$, copper – $R^2 = 0.11$ and aluminum – $R^2 = 0.11$.** © *2023 Bull. Georg. Natl. Acad. Sci.*

cadmium, soil, plant, contamination, *Amaranthus viridis*

Environmental pollutants in the ecosystem have been accumulating intensively for the last century [1-3]. One of the most important ores in Georgia in terms of environmental impact is the Rich Metals Group (RMG) Gold and RMG Copper ores in Kazreti, located in the Bolnisi district, on the right bank of the Mashavera River (southeastern Georgia) [4, 5]. Sulfide ores containing copper ore are processed in an open quarry, resulting in certain concentrations of Cd, Cu, Pb, Zn and other trace metals that are accumulated in the soil over time [5-7]. Naturally the Green Amaranthus (Amaranthus viridis) is quite common in this area [8, 9], it belongs to the Amaranthaceae family [10]. Local population in Bolnisi district use green amaranth for food and prepare various kinds of food from it [9]. Green Amaranthus grows fast in this area and emerges from the soil several times a year. In 2012-2013, we studied soil cadmium contamination in field conditions and the absorption of Cd, Cu, and Zn by the plant Green Amaranthus from these soils. It was found that while decreasing the concentration of Cd in the soil from 2.3 mg/kg to 1 mg/kg the accumulation of Cd, Cu and Zn by the plant significantly increased, although the concentrations of Cu and Zn in the soil were not significantly

changed [9, 11-13]. It was therefore important to study in laboratory conditions the uptake of different metals by Green Amaranthus under conditions of contamination with different concentrations of Cd in the soil.

For this purpose, Green Amaranthus seedlings were transplanted in the pots available in the laboratory from two locations: 1) from the contaminated village of Balichi, Bolnisi district, and 2) from the control village of Kumisi, Gardabani district. The aim of the study was to determine whether the Green Amaranthus absorbs the concentration of Cd in the conditions of contamination with cadmium in the range of 0.5 to 10 mg/kg, and what is the difference between Green Amaranthus plants transplanted from contaminated soils and uncontaminated soils in terms of uptake of Cd from the soil? Does the presence of macro elements in the soil affect the absorption of trace metals by the plant?

## Materials and Methods

**Preparation of soil.** In the laboratory, in 6 pots with a capacity of 15 liters, pre-drained soil cleared of stones and plant roots was placed in each and each pot was artificially contaminated with cadmium solution. Cadmium contamination was performed according to pre-selected concentrations ranging from 0.5 to 10 mg/kg. The names of the pots and the artificially introduced concentrations of cadmium in them are given in the Table.

**Table. Names of treatments and concentration of Cd contained in each treatment**

| Name of the pot | N1 | N2 | N3 | N4 | N5 | N6 |
|---|---|---|---|---|---|---|
| Cd mg/kg | 0.7 | 0.9 | 1.1 | 2.0 | 5.0 | 10.0 |

Plant seedlings were transplanted from two preselected locations. 1) From the contaminated village of Balichi in the Bolnisi district and 2) from the village of Kumisi in the control Gardabani district. Green Amaranthus seedlings were transplanted into pre-prepared pots in the laboratory. In each pot 4 plants were planted, 2 of which were transplanted from a contaminated area (called PlantAmaranthusPollution (PAP) and 2 plants were removed from the control soil (village of Kumisi) and these plants were named Plant Amarnthus Control (PAC). Seedlings in pots were watered periodically. Samples were taken twice during the experiment in September and October.

**Quantification of trace elements in the soil and plant.** After soil samples were taken, they were dried, cleaned and the trace metals Cd, Cu, Pb, Zn, etc. were identified in them.

The acid-soluble forms of trace metals in the soil were identified as follows: the dried soil sample was cleaned from the roots and stones and a 2 g soil sample was taken by the method of division into four parts. After thoroughly squashing the sample in the porcelain bowl, it was sifted through a capron sieve with 1 mm size holes. For acid extraction of metals from the soil sample, pre-dried soil was weighed in a 50 ml flask in the amount of 1.00 g and 10 ml 5 mole nitric acid solution (ratio water: acid = 1: 5) was added. The flask with the presence of counter-refrigerator content was heated over a water bath for 3 hours; the solution was stirred in a circular motion after each hour. After this procedure, the solution was cooled to room temperature and filtered on red or white stripe filter paper. The soil remaining on the filter was washed with distilled water; the volume of the filtrate was filled with up to 50 ml of distilled water. The trace metals in the obtained acid extract were determined using ICP-MS.

To quantify trace metals in plants, their dry mineralization was initially done. The method was based on the process of complete decomposition of organic matter in the test sample by burning the sample in an electric oven at a controlled temperature of 550°C. The color of the product should be gray and there should be no black dots in it.

After mineralization, a mixture (3:1) of nitric acid and hydrochloric acid of 3 ml was added to the ash, which was heated at 50°C for 12 hours, and

after reaching the 50 ml volume of the obtained solution, trace metals were determined using ICP-MS and ICP-OES.

**Calculation of the Accumulation Coefficient.** Accumulation Coefficients of Cu, Zn, Cd, Mo, St, As, Pb, K, Mg, P, Fe, Al and Ca were calculated based on the study data. The Accumulation Coefficient is the relation of the amount of a specific chemical element per 1 kg of mass of plant's given body to the amount of this element per 1 kg of soil.

$$AC = \frac{P_n}{S},$$

where AC is the Accumulation Coefficient, $P_n$ – the concentration of the plant element, $n$ – the lower index, indicates the part of the plant (root, leaf), and $S$ is the concentration of elements in the soil. The formula for the Accumulation Coefficient was introduced in order to identify, what is the ratio of accumulation of this or that element in the plant from the soil.

## Results

A study of plants grown in pots under laboratory conditions found that cadmium uptake by plants was higher when its concentration in the soil was in the range of 1.1 mg/kg. Cd absorption is particularly high in plants transplanted from contaminated areas. We had a similar result when we studied in the field the absorption of cadmium from soil by Green Amaranthus, then Cd concentration was 1.05 mg/kg in the soil by the plant green Amaranthus can absorbed 6.23 mg/kg Cd from the soil [1].

According to data of laboratory studies, when the concentration of cadmium in the soil is equal to 1 mg/kg, the plant Amaranthus absorbs more Cd from contaminated areas than at higher concentrations of this metal. See Fig. 1 below, showing the uptake of Cd by plants.

It should be noted that the concentration of Cd in the soil significantly determines the phyto-remediation properties of plants. According to the study, the uptake of cadmium by PAP is high in pot 2, which was 8.45 mg/kg when the Cd concentration in the soil was 1.1 mg/kg. In the other pots it was 1.18, 0.95, 0.65, 1.68 and 1.27 mg/kg. And PAC cadmium uptake in the plant ranges from 0.5 mg/kg to 1.5 mg/kg. The plant absorbed concentrations in all six pots then ranged from 0.51, 1.01, 1.41, 0.65, 0.72 and 1.1 mg/kg. Also, the absorption of some elements by the plant depends on the concentration of Cd in the soil. According to the investigated data, the Accumulation Coefficient of Cd increases with increasing the concentration of this element in the soil. See Table, where the concentration of Cd in the soil, the concentration of metal absorbed by the plant and the coefficient of accumulation of these plants are given. According to the Fig. 1, in the case of both plants PAP and PAC, it can be seen that the uptake of Cd from the soil by the plant proceeds similarly, except of few differences. The higher the concentration of cadmium in the soil the more the accumulation of cadmium in the PAP plant decreases. The highest amount of cadmium in plant PAP was accumulated in pot 2 when the soil cadmium concentration was 1.1 mg/kg and the plant absorbed 8.45 mg/kg of metal from this pot. As for the PAC plant, the absorption of cadmium from the soil is almost the same, when the concentration of cadmium in the soil is 1.1, 1.3 and 11 mg/kg, respectively, the plant absorbed 1.01, 1.41 and 1.1 mg/kg. Absorption of cadmium by PAP in pots is the same as in a field experiment.

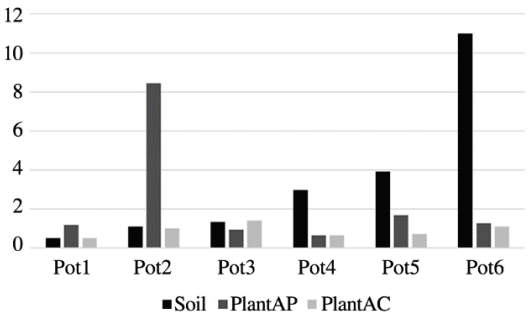


**Fig. 1.** Absorbtion of Cd from soil by plant Amaranthus.

The value of the Accumulation Coefficients of PAP and PAC decrease in parallel with the increase of cadmium concentration in the soil in plants transplanted from both control and contaminated areas.

The relation of the concentration of elements accumulated by the plant Amaranthus and the elements in the soil to the cadmium concentration is shown by regression (see Fig. 2). The picture clearly shows the relationship between zinc and cadmium, where regression has the highest rate: $R^2 = 0.4703$.

As for the other elements, their rates are as follows: arsenic $R^2 = 0.151$, copper $R^2 = 0.1083$ and aluminum $R^2 = 0.1113$. Based on the research data, the other elements have a low regression: $R^2 < 0.09$.

## Conclusion

Studies have shown that Green Amaranthus has the ability to absorb trace metals from the soil. The study found that the absorption of metals by the plant Amaranthus depends on where the plant is transplanted from, contaminated or the control area. According to the study, four groups were identified, which combined different elements that the plant absorbs from the soil in different concentrations. The study found that when the concentration of cadmium in the soil was equal to 1.1 mg/kg, at this time the plant absorbs a higher concentration of cadmium from the soil than under conditions of high soil contamination with this element. The study also found that the amount of Cd accumulated in the plant has a significant effect on the absorption of macronutrients K and P by the plant. As the concentration of cadmium in the soil increases, the absorption of K and P by the plant transplanted from the control and contaminated area decreases.

As for the Accumulation Coefficient, it has different values for different metals, although molybdenum and strontium have high Accumulation Coefficients. Copper is absorbed by both plants – Amaranthus Balichi (PAP) and control one (PAC) by almost the same concentration, although in the case of zinc the Amaranthus Balichi (PAP) is

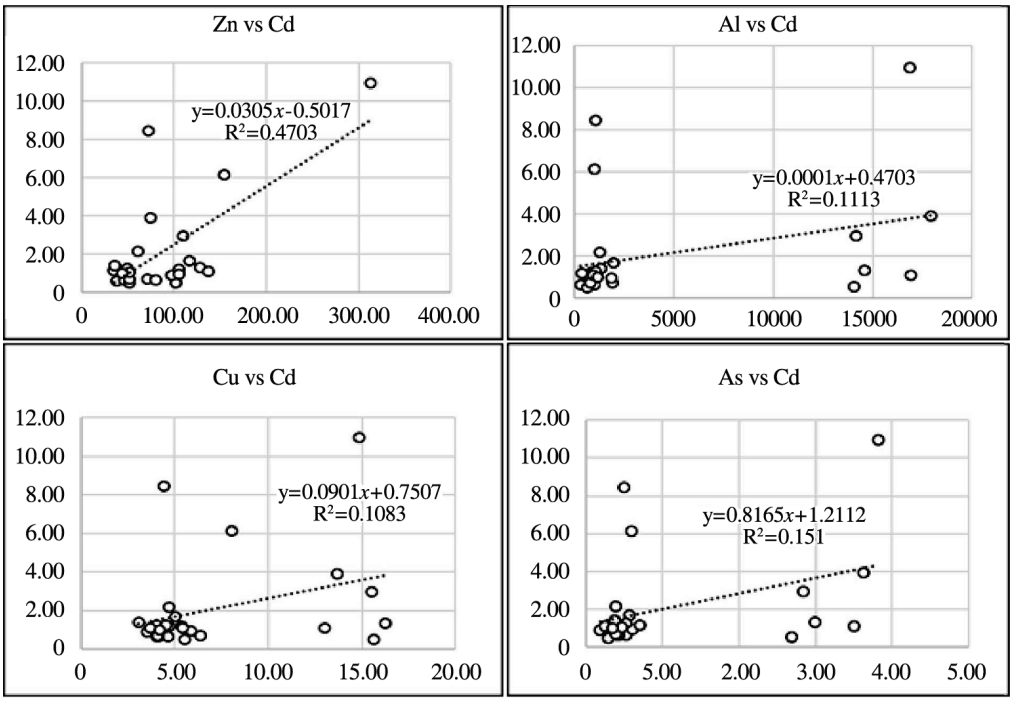


**Fig. 2.** Linear regressions comparing nutrient and toxic element concentrations with Cd.

absorbed in greater quantities than in the control one (PAC). From the studies we can assume that the accumulation of various metals by the plant has a regressive relationship with the concentration of cadmium in the soil and in the plant. Such elements are zinc, aluminum, arsenic and copper.

*ეკოლოგია*

# მცენარე ჯიჯლაყას *(Amaranthus Viridis)* მიერ მაკრო- და მიკროელემენტების ბიოაკუმულაცია კადმიუმით დაბინძურებული ნიადაგიდან

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მთელ მსოფლიოში მწვანე ჯიჯლაყა (მწვანე ამარანდა (Amaranthus viridis)) ძალზედ გავრცელებული ბალახია, იგი იზრდება მრავალ ადგილას და გამოიყენება საკვებად. ჩვენ ჩავატარეთ სასათბურე ლაბორატორიული ექსპერიმენტი, რათა დაგვედგინა მცენარე ჯიჯლაყას მიერ ნიადაგიდან Cd-ის აბსორბციის უნარი, როდესაც კადმიუმის კონცენტრაცია ნიადაგში მერყეობს 0,5-დან 11 მგ/კგ-მდე. მცენარე ჯიჯლაყა შთანთქავს მეტ Cd-ს, როდესაც Cd-ით ნიადაგის დაბინძურება 1 მგ/კგ-დან 1,5 მგ/კგ-მდე კონცენტრაციის დიაპაზონში მერყეობს. 2,9 მგ/კგ-დან 11 მგ/კგ-მდე კადმიუმის კონცენტრაციის დროს მცენარის მიერ ამ ელემენტის შთანთქმა დაბალია და არ აღემატება 1,6 მგ/კგ-ს. კვლევის დროს დადგინდა, რომ Cd-ის კონცენტრაცია ნიადაგში რეგრესიულ ურთიერთობაშია თუთიასთან – $R^2 = 0,47$, დარიშხანთან – $R^2 = 0,15$, სპილენძთან – $R^2 = 0,11$ და ალუმინთან – $R^2 = 0,11$.

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