RESEARCH ON THE GROWTH INTENSITY OF THE *Zea mays* L. PLANTLETS AERIAL PARTS UNDER CADMIUM TREATMENT

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Abstract: In order to test the effect of cadmium on the growth of the plantlets aerial parts, this element was administered as water solutions of cadmium chloride ($CdCl_2$) of different concentrations. The measuring of the length of the *Zea mays* plantlets aerial parts evidenced the existence of some differences regarding the value of this parameter. Analyzing the obtained data, we observe that the inhibiting action of cadmium upon the growth of the *Zea mays* plantlets aerial parts was directly proportional with the increase of the concentration of the applied heavy metal. The lesser values were evidenced at the variants which were treated with the higher concentrations of cadmium chloride (100 mg/l and 200 mg/l). The plants from the variant with 1 mg/l $CdCl_2$ resisted at cadmium toxicity, the inhibition being insignificant. Morphologically, it was observed that as the administered cadmium concentration was increased, the most evidently the symptoms of chlorosis and dryness of the vegetative tops of the *Zea mays* plantlets appeared.

Keywords: caryopsis, cadmium chloride, aerial part, variant, plantlet.

INTRODUCTION

Plants represent the feeding resources for man and most of animals, and their contamination with different pollutants determines the propagation of their elements along the trofic chain [1]. For this reason studying the accumulation of different toxic elements of plants is very important, measures being necessary to face out the destruction of the terrestrial and aquatic ecosystems [11]. The problem of farmland heavy metal contamination has raised serious concerns. Heavy metals are absorbed and accumulated by plants thus are absorbed directly or indirectly by human bodies through the food [3]. The conclusions of most of the discussions, analyses and estimations over the last decades, regarding the future of mankind, underlined that nutrition is the factor which will sustain the demographic growth [9]. Urbanization and the industrial revolution put up severe issues caused by the accumulation of xenobiotics (Hg, Pb, Cd, SO_2, etc.) in air, water and soil, and at the end of the last century the attention was focused on the undesired climate change, as a consequence of pollution (acid rains, greenhouse effect, drought) [7]. The industrial and agricultural development has released enormous amount of heavy metals and polluted the environment. Cadmium is particularly a dangerous pollutant due to its high toxicity and great solubility in water [8]. There is an warning that in the heavy metal polluted areas to grow only technical plants which are resistant and valuable from economic point of view, and do not grow plants which are intended to human or animal feeding [5]. The future development of the industrial activity should be carried out according to the principle of durable development, protecting the environment [6]. Man, as product and part of Nature, in time has become a disturber of the natural ecosystems [10]. In the present, nature protection, environment quality increasing and species conservation should present a major preoccupation for mankind, which has the duty of leaving at the future generations the less altered natural patrimony [15]. Generally, an important characteristic of heavy metals, notwithstanding if they are biologically essential or not, is that in excess they are highly phytotoxic. Although the relative toxicity of different metals can vary relative to the plant genotype and the experimental conditions, the most phytotoxic, in excessive quantities, are: Hg, Cu, Ni, Pb, Co and Cd [12]. Cadmium increases the activity of some hydrolytic enzymes and peroxidase, thus intensifying the respiration and concurring to the acceleration of senescence [2]. However, all heavy metals are potentially toxic for plants, as the margin of beneficial concentrations is usually very narrow. Over the threshold at which heavy metals lead towards the inhibition of growth, a diversity of toxic effects was observed for all the species of plants. Their relative importance depends on the metal nature and concentration. In the research made by [4], the purpose was to investigate the biochemical and physiological answers of the plants to the excess of heavy metals. Wheat (*Triticum aestivum l.*) was chosen as research species, this plant having nutritional importance, as means of transportation of heavy metals towards the superior trofic levels. The results showed that for the tested metals (Cu and Cd), the germination lessened as the concentration of the metal cations increased. The inhibition effect of aerial parts growth was higher with copper than with cadmium. The wheat plants, which were grown in the presence of excessive Cu^{2+} or Cd^{2+}, accumulated in their roots important quantities of these metals, but they translocated about ten times less to their aerial parts. Another study was carried out by [14] with *Raphanus sativus l.*, observing the influence of different concentrations of Pb and Cd on some physiological indicators in the dynamics of the germination process of the seeds and in the first phases of plantlets growth. The conclusion of this research was that, notwithstanding the concentration, Pb and Cd determined the lessening of the respiration intensity, an indicator for evidencing the metabolic activity and the water content, as well as the increasing of the assimilated pigments (excepting Cd in concentrations of 10 ppm).

The purpose of our study was to observe the effects of different concentrations of cadmium (1 mg/l, 5 mg/l, 10 mg/l, 100 mg/l, 200 mg/l $CdCl_2$) on the aerial parts growth for the *Zea mays* plantlets. In this research we tried to follow, for another plant species, a different one from those studied by the above mentioned authors, specifically *Zea mays*, the evolution of the growth of the plantlets aerial parts, increasing step by step the concentration of $CdCl_2$ in the growth medium of the experimental variants. We are especially interested in it, because the soil of the Baia Mare area is polluted with heavy metals such as Pb, Cu, Zn, and Cadmium. On the farming lands of this region mostly grow this studied species, *Zea mays*, and our experiments let us know the cadmium concentration of soil until plants could resist, grow and develop.

MATERIALS AND METHODS

The "Dobrogean" variety of corn was used so as to follow the effect of cadmium on the growth of the plantlets aerial parts. This element was administered as water solutions of cadmium chloride ($CdCl_2$) of different concentrations.

We used 120 corn caryopses, which were kept for disinfection in ethylic alcohol for one minute, then they were washed in running water and soaked in different concentrations of $CdCl_2$, for one hour, with the corresponding solutions of $CdCl_2$ (**S_1** – 1 mg/l $CdCl_2$, **S_2** – 5 mg/l $CdCl_2$, **S_3** – 10 mg/l $CdCl_2$, **S_4** – 100 mg/l $CdCl_2$, **S_5** – 200 mg/l $CdCl_2$), and then they were put for germination. The control was treated only with running water. The soaked kernels were placed on filter paper, each germinator containing 10 caryopses. The corn caryopses were watered daily with $CdCl_2$ solutions, corresponding to each variant, respectively the controls were watered with running water. The germination conditions were ensured by working at constant temperature of 20 ± 1^0C, under natural light. The scheme of the experimental variants was as it follows:

- **S_0** – as control:
- **S_1** – 1 mg/l $CdCl_2$;
- **S_2** – 5 mg/l $CdCl_2$;
- **S_3** – 10 mg/l $CdCl_2$;
- **S_4** – 100 mg/l $CdCl_2$;
- **S_5** – 200 mg/l $CdCl_2$.

The experiments were carried out in three replications, and the results that are exposed in this paper represent the average of the results of the three replications. Daily measuring were made with a scale ruler, determining the length growth of the plantlets aerial parts, commencing from the 7^{th} day since the seeds were put to germinate, and the results were expressed in centimeters. The marked value for the control variant for each experimental day is considered as one hundred percent control, as the values of the other variants are to be compared to it. In order to analyse the results obtained following the growth, the data were processed with some statistic tests: the standard deviation, which represents a measure of the deviation of the experimentally obtained individual values from their average value; the Student's *t* test – with which we could analyze if the calculated coefficient was significant or insignificant.

RESULTS

Measuring the length of the *Zea mays* plantlets aerial parts evidenced the existence of some differences regarding the value of this parameter, for each experimental variant.

After performing the measuring and the statistic analyzing, the obtained data were put in the Table 1. The values represent the average of the data, calculated by following the measuring of the plantlets aerial parts of every variant, and the standard deviation was separately calculated for each value.

Table 1. The growth intensity of the *Zea mays* plantlets aerial parts under Cadmium treatment.

Exp. var. / Days	Average lengths of aerial parts (cm ± Sd)					
	S_0 (control)	**S_1** (1 mg/l $CdCl_2$)	**S_2** (5 mg/l $CdCl_2$)	**S_3** (10 mg/l $CdCl_2$)	**S_4** (100 mg/l $CdCl_2$)	**S_5** (200 mg/l $CdCl_2$)
7	1.4±0.56	1.1±0.14	1.37±0.27	1.05±0.07	0.8±0.45	0.45±0.07
8	1.45±0.42	1.25±0.14	1.4±0.25	1.15±0.21	1.06±0.39	0.63±0.15
9	1.52±0.43	1.81±0.53	1.45±0.23	1.31±0.46	1.3±0.34	1.03±0.05
10	1.75±0.76	2.52±0.79	1.97±0.74	1.66±0.41	1.54±0.18	1.16±0.15
11	3.16±1.39	4.1±0.89	2.52±0.72	2.41±0.77	1.9±0.51	1.43±0.37
12	4.53±1.35	6.1±1.67	4.38±1.38	4.08±1.29	2.34±0.72	1.86±0.77
13	6.77±1.22	7.55±2.4	5.65±1.89	5.1±1.21	3.78±0.98	2.83±1.55
14	8.45±1.39	8.6±2.27	7.64±1.76	6.33±1.17	4.16±1.2	3.1±1.63
15	10.17±1.3	10.11±2.3	8.85±2.37	7.12±1.17	4.22±1.1	3.1±1.63
16	12.65±1.2	11.67±2.9	9.52±2.37	7.65±1.36	4.22±1.1	3.1±1.63
17	14.5±2.78	13.16±3.4	10.25±2.1	8.17±1.6	4.22±1.1	3.1±1.63

Note: Sd = Standard deviation

In order to analyze every set of values, we used, as a measure, the values of the growth of the plantlets aerial parts on the control solution, from which we percent related the values of the growth of the plantlets aerial parts on the solutions which were treated with different cadmium concentrations, as shown in Fig. 1.

DISCUSSIONS

Analyzing the data from Table 1, we observe the inhibiting action of cadmium upon the growth of the total length of the *Zea mays* plantlets aerial parts, directly proportional with the increase of the concentration of the applied heavy metal. The lesser values of the length of the aerial parts were evidenced at the variants which were treated with the higher concentrations of cadmium chloride (100 mg/l and 200 mg/l). The less affected was the $\mathbf{S_1}$ variant, which was treated with the less concentrated cadmium solution (1 mg/l), sometimes the recorded values exceeding the lengths of the aerial parts of the control lot $\mathbf{S_0}$. This statement could be explained as the total lengths of the plantlets aerial parts of the $\mathbf{S_1}$ variant was less than those of the control ($\mathbf{S_0}$) in the 7th and 8th experimental days, as higher values of the growth were recorded in the 9th-14th experimental days period, and the lesser values versus the control were recorded in the 15th-17th experimental days period.

Morphologically, it was observed that as the administered cadmium concentration was increased, the more evidently appeared the symptoms of chlorosis and dryness of the vegetative tops of the *Zea mays* plantlets.

For the highest concentration of cadmium chloride treated variants ($\mathbf{S_4}$ - 100 mg/l $CdCl_2$ and $\mathbf{S_5}$ - 200 mg/l $CdCl_2$), the growth of the plantlets aerial parts stagnated and the plantlets aerial

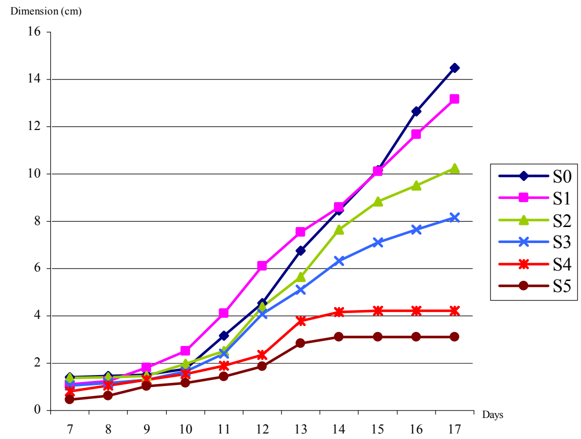

Figure 1. The dynamics of the values regarding the total length (cm) of the *Zea mays* plantlets aerial parts, obtained by the germination of the caryopses and subsequently growing the plantlets on substrata containing variants with different concentrations of $CdCl_2$ solutions: distiled water ($\mathbf{S_0}$ – as control); with 1 mg/l $CdCl_2$ ($\mathbf{S_1}$ variant**),** 5 mg/l $CdCl_2$ ($\mathbf{S_2}$ variant), 10 mg/l $CdCl_2$ ($\mathbf{S_3}$ variant), 100 mg/l $CdCl_2$ ($\mathbf{S_4}$ variant) and 200 mg/l $CdCl_2$ ($\mathbf{S_5}$ variant), in the 7th-17th days period since putting them to germinate.

Table 2. The data regarding the growth rate (cm) of the *Zea mays* L. plantlets aerial parts treated with different cadmium concentrations.

Days \ Var.	S_0 (control)	S_1 (1 mg/l $CdCl_2$)	S_2 (5 mg/l $CdCl_2$)	S_3 (10 mg/l $CdCl_2$)	S_4 (100 mg/l $CdCl_2$)	S_5 (200 mg/l $CdCl_2$)
7 – 9	0.12	0.71	0.08	0.26	0.5	0.58
9 – 11	1.64	2.29	1.07	1.1	0.6	0.4
11 – 13	3.61	3.45	3.13	2.69	1.88	1.4
13 – 15	3.4	2.56	3.2	2.02	0.44	0.27
15 – 17	4.33	3.05	1.4	1.05	0	0

Table 3. The values of the *t* test for the *Zea mays* plantlets aerial parts (where $\mathbf{S_1}$ - substrate was soaked with 1 mg/l $CdCl_2$; $\mathbf{S_2}$ – with 5 mg/l $CdCl_2$; $\mathbf{S_3}$ – with 10 mg/l $CdCl_2$; $\mathbf{S_4}$ – with 100 mg/l $CdCl_2$; $\mathbf{S_5}$ – with 200 mg/l $CdCl_2$).

Days \ Var.	S_1		S_2		S_3		S_4		S_5	
	t	significance	*t*	significance	*t*	significance	*t*	significance	*t*	significance
7	0.72	-	0.07	-	0.86	-	1.32	-	2.35	*
9	-1	-	0.34	-	0.82	-	0.88	-	1.87	-
11	-2.43	-	1.7	-	2.04	*	1.97	-	2.1	-
13	-1.23	-	2.08	*	4.10	*	5	*	5	*
15	0.08	-	2	-	6.96	*	8.55	*	7.78	*
17	1.27	-	5.06	*	8.36	*	4.27	*	3.65	*

Note: - = non-significant values; * = significant values.

parts turned brown in the 16th and 17th experimental days.

Considering the obtained data, we observe that the most resistant plantlets versus the action of cadmium were those of the $\mathbf{S_1}$ variant, which in the 7th day of the experiment had the total length of the aerial parts as 78.5% of the total length value of the aerial parts of the control; and subsequently, a higher value of the total length of the aerial parts of the plantlets was recorded during the 9th-14th experimental days period than for the control lot. The lengths of the plantlets aerial parts of the of the $\mathbf{S_1}$ variant in the 12th experimental day represented 134.6% of the length of the plantlets aerial parts of the control lot. This result could mean that, when cadmium was administered in small quantities, it could had a stimulating effect, accelerating the metabolic processes, and the plantlets were able to elaborate some adaptive strategies, becoming more resistant versus the action of this metal. Instead of it, the lengths of plantlets aerial parts of the $\mathbf{S_1}$ variant were smaller at the end of the experiment, in the 17th day, it representing 90.7% of the value recorded for the control, which means that after a period of more days, the toxic action of cadmium determined a small reduction of the length growth of the plantlets aerial parts versus the control.

For of the $\mathbf{S_2}$ experimental variant, a length of 97.8% of the length of the plantlets aerial parts of the control was recorded in the 7th experimental day, and this value was reduced to 70.6% of the value of the control at the end of the experiment, in the 17th day; this means that the toxic action of cadmium affected the growth of the plantlets aerial parts of this variant.

The $\mathbf{S_3}$ experimental variant comprised the plantlets that in the 7th day of the experiment presented the length of the aerial parts of 75% of the length of the aerial parts of the control, and a value of 56.3% of the length of the aerial parts recorded for the control lot at the end of the experiment, in the 17th day; thus the toxic effect of cadmium was more significantly manifested than in the latter case.

The highest modifications of the growth of the aerial parts of the plantlets were recorded for the S_4 and S_5 variants. Thus, for the S_4 variant, a value of 57.1% of the length of the aerial parts of the control was recorded in the 7th experimental day, and this parameter became 29.1%, by the end, in the 17th experimental day.

A value of 32.1% of the length of the aerial part of the control was recorded for the S_5 variant in the 7th experimental day, and the value became 21.3% of the length of the aerial part of the control, by the end, in the 17th experimental day.

These results show that the plantlets from the variants S_4 and S_5 that were treated with the most concentrated cadmium solutions could not resist the toxicity of cadmium. Stagnation of the growth of the plantlets aerial parts and an intense phenomenon of leaves chlorosis were observed in the 16th and the 17th experimental days.

Comparing the values of the aerial parts growth of the S_0 variant (control) with the values of the S_1 variant (1 mg/l/$CdCl_2$), we observe that although in the 9th-14th experimental days interval there was a period in which the total length of the aerial parts of the S_1 variant recorded a higher value than in the case of the control, the lengths of the plantlets aerial parts of the S_0 variant were higher by the end, in the 15th-17th experimental days period (Fig. 1).

Comparing the control variant with the S_2 variant, the toxicity of cadmium was more significantly manifested than for the previous variant, the differences being higher, reaching the value of 70.6% of the length of the aerial parts of the control, in the 17th experimental day.

The toxic effect of cadmium was more strongly manifested for the S_3 variant, in a higher extent inhibiting the development of the aerial part comparatively with the control lot. We observe an inhibition of the growth of the length of the plantlets aerial parts for the S_4 variant (100 mg/l $CdCl_2$), reaching 29.1% of the length recorded for the control by the end of the experiment, in the 17th day, and for the S_5 variant (200 mg/l $CdCl_2$) reaching 21.3% of the length recorded for the control by the end of the experiment, in the 17th day (Fig. 1).

In Table 2, we observe that the highest growth rate was recorded for the control at the end of experiment, in the interval of the 15th-17th experimental days, followed by the S_1 variant, for which it was higher than for the control within the intervals of the 7th-9th and 9th-11th days. For the S_2 and S_3 variants the minimum value of the growth rate was within the interval of the 7th-9th days, and the maximum value within the interval of the 13th-15th days and respectively the 11th-13th experimental days interval.

In the case of the S_4 and S_5 variants, a minimum rate of growth was recorded in the interval of the 15th-17th days, when the plantlets could not any more resist the toxicity of cadmium.

From the obtained data, following the *t* test (Table 3), we observe that the most significant modifications appeared at the variants S_4 and S_5. The plants from the variant S_1 managed to resist the cadmium toxicity, but for the variants S_2, S_3, S_4 and S_5 the inhibition of the aerial parts growth was significant under the action of different concentrations of cadmium.

The influence of heavy metals on the physiological processes of plants was studied by [13], who observed the growth of the whole plant and the chlorophyll content, oxygen evolution, and chloroplast ultrastructure of leaf tissues. These were studied in *Zea mays* plants grown on a culture medium either without cadmium (Cd) or supplied with increasing concentrations of the metal. The plants treated with high Cd concentrations showed symptoms of heavy metal toxicity, such as length reduction of both roots and shoots, leaf bleaching, ultrastructural alterations of chloroplasts and lowering of photosynthetic activity. Some symptoms appeared at 100 mg Cd, but the strong toxic effect of the metal was found only with 250 mg Cd. In the experiment carried out by [13] we observe the way in which the heavy metal, cadmium, influences some physiological processes of the *Zea mays* plantlets. Coming back to our study, we used in our experiment the same species, *Zea mays*, and the same heavy metal, cadmium, but unlike [13], we followed another parameter, respectively the growth of the total length of the plantlets, gradually increasing the concentration of cadmium in the growth medium. We could conclude that in our experiment, if using different concentrations of cadmium, the growth of the aerial parts was inhibited directly proportional to the different concentrations of cadmium, at the end, in the 17th day. Morphologically, at the aerial part of the *Zea mays* plantlets, we observe the symptoms of chlorosis and dryness of the vegetative tops, as more pronounced as cadmium was administered in higher concentration. We observe that the most significant modifications appeared at the experimental variants S_4 (100 mg/l $CdCl_2$), and S_5 (200 mg/l $CdCl_2$). The plants from the S_1 (1 mg/l $CdCl_2$) variant were able to resist the toxicity of cadmium, the inhibition being insignificant. Analyzing the results obtained by the previous description, we observe that the same kind of research was carried out by [14], who concluded that, when the *Zea mays* plantlets where subjected to concentrations higher than 250 mg Cd, the abrupt lowering of the photosynthesis and implicitly the radical reduction of the plants growth appeared. Our study shows that at the lowest concentration of cadmium taken into consideration (1 mg/l), the plants were able to resist the effect of cadmium; this is why the modifications of the lengths growth of the plantlets aerial parts were insignificant.

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