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PECULIARITIES OF ACCUMULATION OF SOME HEAVY METALS ON THE CHAIN OF WATER-SOIL-PLANT

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ABSTRACT

The impact of some heavy metals (Zn, Cu, Mn) by accumulation activity of seeds maize through migration way water-soil-plat was studied. Comparison of kinetic covers of the maize growth cultivated in open field and in the laboratory chamber with controlled condition allows us to note that the Armenian corn was investigated in natural conditions, and the inbred line B73 was investigated in laboratory with a maximum close to natural. As the plant grows in the field, changes are observed in the physiological parameters of growth, which are close in terms of indicators for a severe drought in the laboratory. The concentration of Zn, Cu and Mn in the triad of water-soil-plant during the maturation of the plant, which was grown on semi-desert brown soil and was irrigated with artesian water of the Araks River basin, was determined. The concentration changes some of heavy metals in corn grains may be caused by an increased content of the latter in the soil as a result of the use of contaminated irrigation water. The obvious migration of pollutant metals along the water-soil-plant chain is a serious threat to the environment and biota, for food safety.

Key Words: Maize, drought, kinematic analysis, heavy metal

1. Introduction

At present, the human impact on the environment is larger than the ability of nature to self-recover. Especially the danger is migration of pollutants along the water-soil-plant chain (Wang B., Wang Y. et al, 2014). The toxic elements through the surface water get to the soil, where a variety of plants intensively grow, including those actively consumed by man in everyday food.

The effect of pollutants and compounds can be observed tens of kilometers from the very source of heavy metals (HM) entering the environment (Angelovičová *L.* and Fazekašová D., 2014).

In this context, the phyto-toxic effect of HM is manifested at the level of techno genetic contamination of soils by them and largely depends on the properties and peculiarities of the behavior of a particular metal (Bayseitova N.M., Sartaeva Kh. M., 2014). The study is complicated by the fact that in the natural environment, metal ions rarely occur in isolation from one another.

Their various combinations lead to changes in the properties of individual elements as a result of their anthropogenic impact on living organisms. Plants, especially used as food, are the main source receipts of HMs in the human: 40-80% of HMs comes through plants; 20-40% comes through air and water (Shinwari K. I., Shah A., et al, 2015). Obviously, the chemical composition of the plant is also subject to change, since the redundancy of the HMs concentration is provoked by changes in the latter both in surface waters and in the soil.

Here we investigated the accumulation and character of the localization of Zn, Cu, and Mn in mature grain of corn (Zea mays) cultivated in the soil-climatic conditions of the Ararat region of Armenia.

2. Materials and methods

2.1Biological material

The experiments used a semi-toothed sugar corn of the Armenian population (Zea mays), grown in open field conditions in suburb of Artashat of Ararat region, and as a control plant of maize of inbred line B73 (Iowa Stiff Stalk Synthetic).

Simulation of drought was carried out in a growth chamber under controlled conditions: 16h day / 8h night, respectively 25^0C / 18^0C, humidity 20%, photosynthetic active radiation 300μE · $m^{-2}C^{-1}$, which is provided by high-pressure gas-discharge lamps (Department of Biology, University of Antwerp, Belgium). Plots with corn seeds were watering daily at the same time of day. Soil Water Content (SWC) was maintained at 54% in control vases. Simulation of drought was carried out by changing quantitatively of watering. In the case of moderate drought, SWC was 43% with no visible wilting of the leaves. During the simulation of severe drought, SWC was 34% and leaf wilting was observed during the day. In order to determine the physiological indicator of maize growth under simulated drought conditions, the length of the fifth maize sheet (length from ground level to the end of the foliage) was measured during the first three days of its growth in all three conditions of irrigation. Some kinetic growth parameters of maize under simulated drought conditions by measuring the elongation of the fifth leaf to a statistically significant slowing of its growth were measured.

2.2. Preparing the plant (corn grain)

The mature grains of corn were dried by methods of air-dry drying in a fume hood until an air-dry state at room temperature. Then grains of the plant material was placed in a muffle furnace using pre-claimed porcelain cups at a temperature of + 400 ℃ for 0.5...1 hours for washing. After getting ashes of the samples were placed in desiccators until establishment a constant weight of the dry residue to further instrumental measurements.

2.3. *Preparation of water (water samples)*

Samples of one-time water samples were taken during the spring-summer period of 2016 in order to study the chemical composition and identify sources of pollution of the water object. The depth of the artesian well was 13 m, although the filling with water was observed at a depth of 8 m of the well. Sampling of water was carried out under dry natural conditions at the same time. Samples of water samples taken in special containers were transported in cold conditions (+4 ℃) for laboratory instrumental measurements within 24 hours. In the laboratory, in first weighed a clean empty glass cup. Then, filling the sample with water, putted a cup in a fume hood (up to 14 hours at room temperature), leading to an air-dry state by air drying. After again weighed the cup together with the precipitate and determined the weight difference between the empty and full cup as the weight of the dry residue. In the instrumental measurement, the resulting dry residue was used.

2.4. *Soil preparation*

Samples of soil under dry weather conditions by the envelope method from the depth of growth of the root system of the plant under study were selected, which averaged 1.20-1.70 cm. Sampling was carried out using a non- metal containing tools. The combined sample of soil was made by mixing point samples, from at least five point samples taken from a single test site. After collecting soil, the samples were placed in dark glass containers and moved at a temperature of + 4 ℃ for laboratory (instrumental) measurements for 24 hours. The samples of soil were transferred to the tracing paper and were crushed big soil lumps. After cleaning from the remnants of the root system, insects and other solid constituents, the soil was ground in the foot with a pestle and sieved through a sieve with a whole diameter of not more than 1 mm. To avoid re-contamination, soil samples were dried to an air-dry state in a fume hood, obtaining a sample for instrumental measurement.

2.5. *Measurement of the concentration of chemical elements.*

The prepared samples (maize grains, dry residue of water and crushed soil) were placed in standard XRF cup of the Thermo Scientific™ Niton ™ XRF Portable Analyzer with a diameter of 32mm, then covered with a lavsan film and directly measured by direct X-ray direction on the specimen in total up to 210 seconds. The obtained results were compared with the adopted normative standards.

2.6. *Statistical Analysis*

For all of measurements a two-way ANOVA was performed (factor 1- the stress treatment; factor 2-the heavy metal concentration) using the statistical package SPSS (version 20; IBM). Data are presented as means of ten biological and six technical replicates ± Standard error. All results were considered significant at $P<0.05$.

3. Results and discussion

One of the main indicators of the quality of agricultural crops and the effectiveness of technologies for their cultivation is the elemental chemical composition of plants. In this context, complete information on the environmental safety of the products can be obtained as a result of multi component diagnostics, which makes it possible to evaluate the physiological needs of plants in the elements and determine their concentration changes.

The diversity of the physic-geographical conditions of the Araks basin contributes to the formation of numerous types of soils suitable for the development of the private household farming sector. In this context, an important environmental factor is drought, which directly affects the growth of plants and their reproductive qualities (Al-Kaisi M.M., Elmore R.W., et al., 2013). Therefore, cultivation of drought-resistant plants is very important for the southern territories of Armenia.

In the initial stage of the experiments, we set out to determine the kinetic parameters of the growth of maize grown in the field for a certain climatic zone. The Ararat region is characterized by dry weather conditions, almost without precipitation, with an average annual temperature of + 29 ... 35 ° C. For this purpose, the kinetic parameters of the growth of two maize varieties were compared: the sugar half-toothed maize of the Armenian population and the inbred line of maize B73. The obtained kinetic curves are shown in Fig. 1.

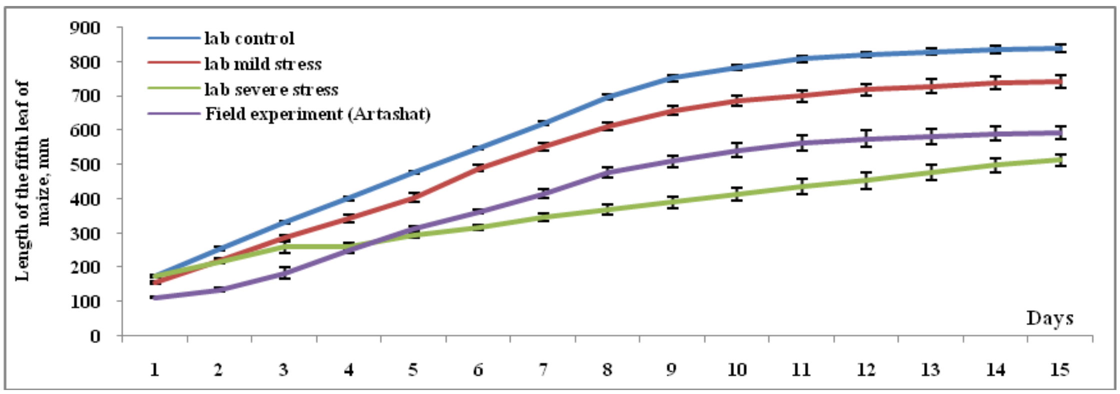

Figure 1. The growth of maize with different contrasting drought tolerance and under control, mild (no leaf wilting), severe (leaf wilting) drought and field conditions.

It should be noted that the Armenian corn was investigated in natural conditions, and the inbred line B73 was investigated in laboratory with a maximum close to natural. This research approach allows to simulate the conditions of moderate and severe drought by choosing the watering regimes of experimental plots (in the control experiment, the SWC in the plot was maintained at 54%, with moderate stress the SWC in plot was 43%, and under severe stress, 34% respectively). The growth kinetics of a sample of the corn plant of the inbred line B73 has been studied in detail (Schnable P.S., Ware D, et al 2009) which allows to compare the obtained results with the results of experiments carried out under field conditions with rather high reliability.

At the initial stage of the experiments to identify the kinetic features of plant growth, the value of the leaf elongation rates (LER) of the fifth maize sheet was determined as an indicator of plant growth. The value of LER is determined by daily measurements of the length of the fifth leaf of the plant during the first three days of the steady growth from the surface of the earth to the end of the fifth leaf. According to the obtained results, shown in the figure, the value of the LER of the Artashat sample is close to the value of the LER for sample B73 in case of moderate stress. As the plant grows in the field, changes are observed in the physiological parameters of growth, which are close in terms of indicators for a severe drought in the laboratory.

Thus, the background (natural) adaptation of the plant is quite consistent with the results of drought modeling (Sharp R.E., Poroyko V., et al.,2004). In the process of plant adaptation, the concentration changes of HM in the environment play an important role, especially in drought (Moussa H.R. and Abdel-Aziz S.M., 2008). The main sources of HM in this region are local incineration and boiler plants, motor transport and agriculture. At the same time, the danger is not only the fact of the entry of polluting metals, but also their migration along the main constituents of the biota (water-soil-plant) with further ingress into the human organism (Wuana R.W. and Felix E. Okieimen F.E., 2011).

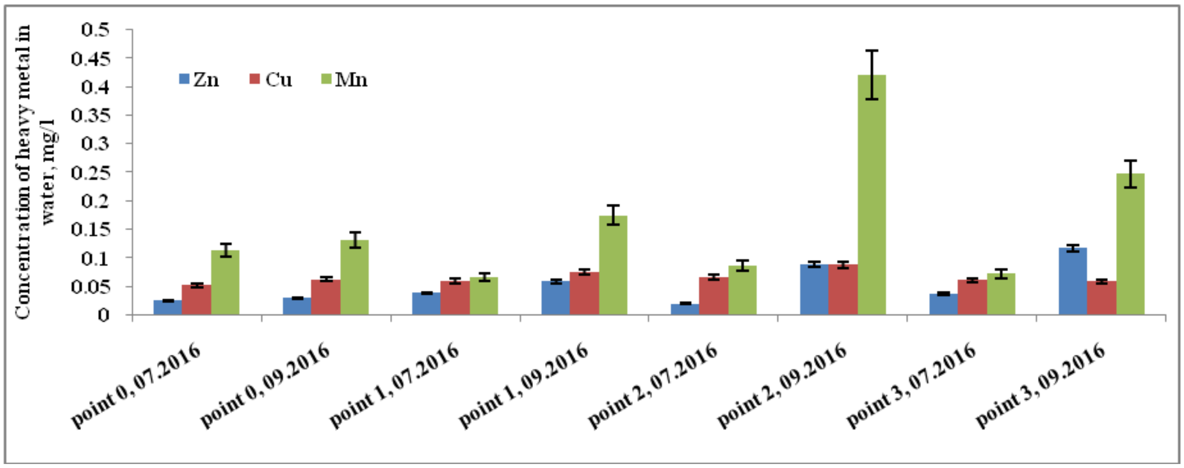

Figure 2. The concentration of heavy metals (Zn, Cu, Mn) in the water samples depending on place and time of collecting

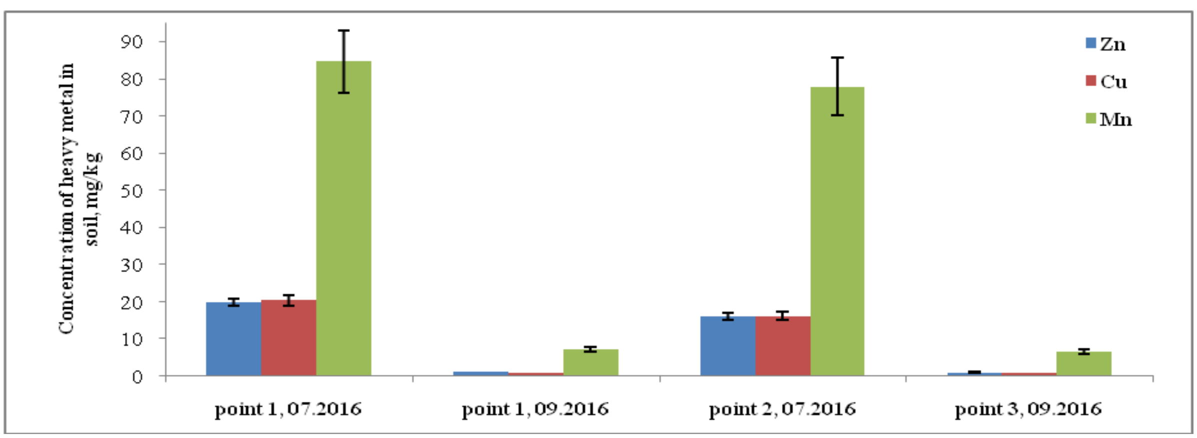

Figure 3. The concentration of heavy metals (Zn, Cu, Mn) in the soil samples depending on place and time of collecting

In subsequent experiments, we determined the concentration of Zn, Cu and Mn in the triad of water-soil-plant during the maturation of the plant, which was grown on semi-desert brown soil and was irrigated with artesian water of the Araks River basin. The listed HMs is typically localized in mature grain of corn (Wang B., Wang Y. et al., 2014). The points of collecting of the samples of artesian water, soil and plant samples were located at fixed distance in according our set task for studying the migration of HM. The first water collect was carried out directly from the artesian well (point 0), then the way of water flow through the soil irrigation canal to the first planting site was 11 m. Here, the samples of water, soil and plants were collected (point 1). Then, following the soil irrigation canal with a length of 1.2 m, water entered the next marked place of sowing and collecting of the samples (point 2). The final location of the sowing and subsequent collect of the samples under study was 1.5 m from point 2 (point 3). The collecting of mature grain of corn and irrigation water was carried out before the beginning of the sowing works and after their completion. In total, the time of field work was about three months (July-September, 2016).

A comparison of the results obtained indicates that determined HMs in the largest quantities are concentrated in maize grains (Fig. 4), the volumes of metal absorption and the nature of localization in plant tissues largely depend on the features of the soil-climatic conditions of agrocenosis (Figures 2 and 3), which the high productivity by intensive technology of selection of high-yielding plants, fertilizers is provided. According to the results shown in Fig. 2, manganese has more quantities in water and zinc - less among the measured the TM. This dynamics of the content of metals in artesian water is maintained after three months at all collection points of the material.

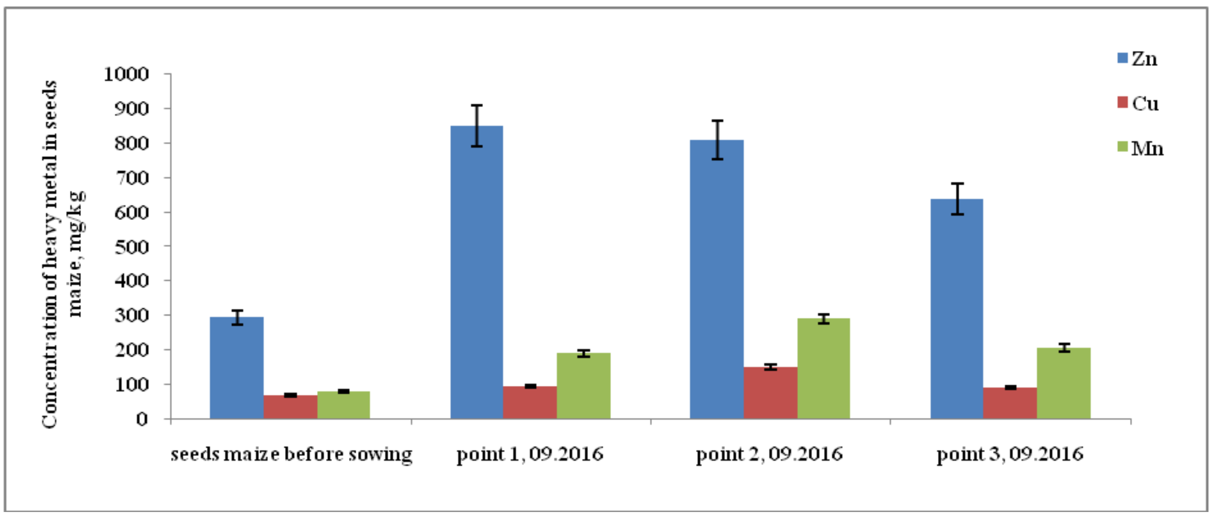

Figure 4. The concentration of heavy metals (Zn, Cu, Mn) in the maize seeds samples depending on place and time of collecting.

Comparing the concentration changes in Zn, Cu and Mn in soil samples at the beginning of field work (July), a high manganese content was noted (point 1 - 84.646 mg / kg, point 3 - 77.929 mg / kg) exceeding the concentration of zinc and copper in a total of almost Four times (point 1 - 19.982 mg / kg and 20.433 mg / kg, item 3 - 16.105 mg / kg and 16.215 mg / kg, respectively).

After three months, the pattern of accumulation of metals-pollutants at times decreased, and keeping the general trend. In this case the concentration of Mn was 7.188 mg / kg in point 1, and 6.644 mg / kg in point 3, exceeding the content of Zn and Cu in soil samples by almost 7 times (Fig. 3). Actually that as the water is removed from the well (point 0), the accumulative activity of the plant depends on the content of these elements both in water and in soil (point 3). After three months, an increase in the concentration of all three HMs intakes is observed. Although in the case of zinc, the concentration of which was not high, the accumulating capacity of the plant is most clearly impression.

Thus, that the concentration changes some of HM in corn grains may be caused by an increased content of the latter in the soil as a result of the use of contaminated irrigation water (Jian-Kang Zhu, 2016; Sukiasyan A.,2016).

The obvious migration of pollutant metals along the water-soil-plant chain is a serious threat to the environment and biota, for food safety, and therefore for the health of the person himself, which together is currently one of the most important causes of environmental risk to humans and plants.

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