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Antioxidant Capacity of Maize Corn under Drought Stress from the Different Zones of Growing

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***Abstract*—**The semidental sweet maize of Armenian population under drought stress and pollution by some heavy metals (HMs) in sites along the river Debet was studied. Accordingly, the objective of this work was to investigate the antioxidant status of maize plant in order to identify simple and reliable criteria for assessing the degree of adaptation of plants to abiotic stress of drought and HMs. It was found that in the case of removal from the mainstream of the river, the antioxidant status of the plant varies. As parameters, the antioxidant status of the plant has been determined by the activity of malondialdehyde (MDA) and Ferric Reducing Ability of Plasma (FRAP), taking into account the characteristics of natural drought of this region. The possibility of using some indicators which characterized the antioxidant status of the plant was concluded. The criteria for assessing the extent of environmental pollution could be HMs. This fact can be used for the early diagnosis of diseases in the population who lives in these areas and uses corn as the main food.

***Keywords*—**Antioxidant status, maize corn, drought stress, heavy metal.

I. Introduction

ENHANCING the migration of man-made materials into the soil, water, and air negatively affects the state of biota and promotes the formation of new human pathologies. In the environment, the concentration of toxic elements – HMs increase [1]. This leads to the violations of vital functions in all living organisms, including plants, animals, and humans. Together with this background, the content of many necessary elements significantly reduced. Similar changes, especially dangerous ones near the river, which are characterized by anthropogenic changes in biota initially, reduced the number of trace elements in soils.

Increasing the level of HMs in the environment results in an imbalanced microelement composition of the human body and stimulates the development of many diseases [2]. However, the successful solution of this kind of tasks necessary to search for reliable criteria and new approaches to assess the extent pollution, are not directly related to the self-study of mankind. One approach could be the study of the vegetation contaminated territories. Plants are fairly sensitive to the elevated levels of HMs in the environment and they are easy for analyzing [3]. The appearance of negative symptoms in plants can serve as an indicator of increasing concentrations of HMs under the drought stress in the environment.

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In view of the above, large-scale studies, which aim to determine the degree of tolerance for the corn plant toxicity of a number of metabolically active HMs before considering their possible use as phyto-indicators of soil stabilizers and in the mountainous areas taking into account the contamination of HMs, were started.

II. Materials and Methods

The objective of the present study was to use the samples of the semidental maize of Armenian population, which are differed by the growing region on the territory of Lori region near the Debet River: Shnokh - sample 1, Teghut - sample 2, Odzun - sample 3.

To model the drought stress, maize plants were grown in a special growth chamber under the controlled conditions (16h day/8h night, 25 °C/18 °C day/night [d/n], humidity: 20%, 300 $\mu E.m^{-2}s^{-1}$ PAR (Photosynthetically Active Radiation)). The pots with the control plant were re-watered daily for supporting the level of Relative Soil Water Content (RSW) of 54%. In the case of modeling the drought water stress, RSW was 43% for mild stress (no wilting), and 34% for severe stress (leaves are wilting during the day), respectively. For the molecular analyses, the fifth leaf during the steady-state growth on the third day of its appearance was harvested. The growth (length) of this leaf is measured daily. A significant difference in the leaf elongation rate and in the final leaf length between the controls and the plants subjected to drought was observed.

To determine the antioxidant status of plants, concentrations of MDA [4] and FRAP [5] of the fifth leaf of the plant have been identified.

The concentration of metabolically active TM (Fe, Ni, Zn, Mo, Mn, Cu) in biological material was determined by atomic adsorption spectroscopy content which was calculated in mg/kg (ppm) molar concentration and compared with the standard indicators [6].

All the experiments consisted of 10 biological and 3 ÷ 5 technical replicates. The results were processed by using a MATLAB program [7].

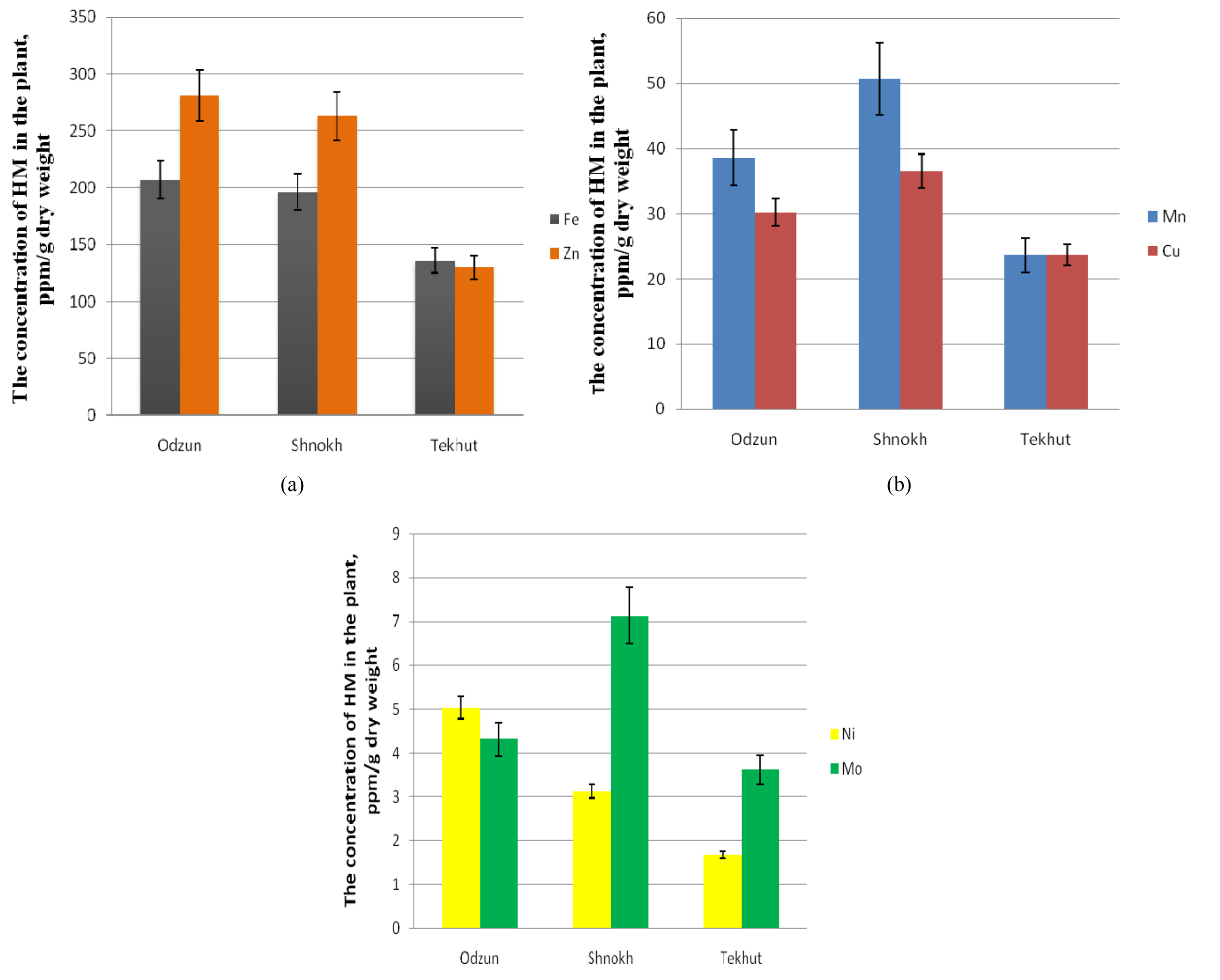
III. Results and Discussion

The variety of physiographic conditions of Debet basin contributes to the formation of many types of soil, suitable for the development of the private sector. The soil covered by Debet River reflects the development of the mining industry too. In this connection, pollution of the valley Debet by HMs has both natural and anthropogenic properties, which contribute to the intensive soil degradation, even *in vivo*. That is why a solution to reduce and prevent the soil degradation becomes more important than the studies aimed at restoring the damaged lands.

The contamination with HMs is a worldwide problem, because it is fraught with its bioaccumulation in the food chain. In this case, the final result of human impact is the accumulation of HMs in the soil, which often exceeds the norm of toxic levels, creating a direct threat to the environment and human health [8]. In this context, the quality of the environment can be assessed by using a biological material - a plant which is capable of absorbing and accumulating HMs [9]. It is also known that some ions remain in the cytoplasm and induce the oxidative stress through the generation of reactive oxygen species. Thereby, the effectiveness of the antioxidant protection of plants is the most important parameter in the study of their resistance to the HMs [10]. For this reason, the concentration of Fe, Ni, Zn, Mo, Mn, Cu in the grain of corn was determined [11]. According to the results, the quantitative content of the six measured items can be divided on three groups. The greatest concentration was different for iron and zinc, especially for the samples from Odzun. Further down the river, the content of these HMs is reduced by an average of 34% in the case of iron and 54% in the case of zinc (Fig. 1 (a)).

In the biological material from Shnokh, the average concentration of manganese was 52%, whereas the average concentration of copper was 38% (Fig. 1 (b)).

A completely different situation was obtained in the case of measuring the concentration of the third pair of TM: molybdenum and nickel. These chemical elements were differed very low concentration. In the biological sample from Shnokh, the concentration of Mo was high in comparison with the concentration this chemical element in the plants from Odzun and Tekhut. Different concentrations of Ni in the plant samples were observed. The concentration of this chemical element was almost by two orders of higher in plants from Shnokh and Tekhut (Fig. 1 (c)).



(c)

Fig. 1 The concentration of some the metabolically active HMs (a - iron, zinc; b - manganese, copper; c -molybdenum, nickel) in biological material (the grain of maize)

Drought stress which is one of the most common stresses for the plants can occur when the water supply to the roots is limited or when the transpiration rate is too high. These two conditions usually coincide with arid and semi-arid climates.

It is known that the availability of drought stress limits the photosynthesis activity due to the imbalance between light capture and its utilization so that oxidative stress also happens [12]. During stresses, active solute accumulation (i.e., soluble carbohydrates, proteins, and free amino acids) is claimed to be an effective stress tolerance mechanism [13]. Reactive oxygen species are generated in response to the environmental stresses such as drought and HMs.

Oxidative (redox) status plays a central role in the plant growth responses to the stress conditions although the potential interaction with the regulation of cell division and expansion has not been resolved. The effects on these regulatory pathways could subsequently have been showed by a detailed biochemical analysis for the quantification of antioxidant metabolites. The microarray already provided a molecular basis for the observed inhibition of cell division rates and also it pointed at the distinct effects in both antioxidant and redox systems [14], [15].

It was mentioned that the maize was grown under different levels of exposure to the drought stress. The mild drought stress has increased the catalase activity, but severe stress decreases it. The drought stress significantly increased the superoxide dismutase activity. At the mild water stress level, peroxidase activity met its maximal level; however, at the severe water stress, its activity was suppressed and even fell below the control level [16]. Our measurements of the "antioxidant capacity" of the leaf under the drought stress have shown that the antioxidant capacity increased with increasing drought stress, but it was relatively homogeneous in the various developmental zones.

In the further experiments, the antioxidant status of the various areas has been determined. The results are shown in Table I.

TABLE I
CONCENTRATION OF MDA FOR THE PLANT TISSUE UNDER DIFFERENT DROUGHT STRESS (MMOL/L)

Sample	Odzun	Shnokh	Tekhut
Control	3.733 ± 0.076	2.366 ± 0.048	2.890 ± 0.036
MD stress	4.475 ± 0.051	5.454 ± 0.022	2.411 ± 0.094
SD stress	8.415 ± 0.217	6.434 ± 0.953	5.155 ± 0.029

MD stress - Mild drought stress, SD - Severe drought stress

It was revealed that the maize samples, which grow in Odzun have the highest value of MDA which is one of the products of oxidation of lipid structures of biological material.

Another indicator for the antioxidant status is FRAP in the oxidative damage to tissues (Table II). The FRAP assay was employed to estimate the antioxidant capacity of the samples in vitro. According to the obtained results, the plants from Odzun have the maximum values of FRAP in comparison with the other samples.

It should be noted that HMs are participating actively in the regulation of oxidative processes and they can serve as a criterion for evaluating the state of the system at their high content in the environment.

TABLE II
CONCENTRATION OF FRAP FOR THE PLANT TISSUE UNDER DIFFERENT DROUGHT STRESS (MMOL/L)

Sample	Odzun	Shnokh	Tekhut
Control	522.494 ± 55.307	267.801 ± 14.365	140.418 ± 16.249
MD stress	768.922 ± 129.418	392.898 ± 43.122	102.711 ± 7.312
SD stress	715.612 ± 45.861	421.966 ± 34.679	239.398 ± 4.010

MD stress - Mild drought stress, SD - Severe drought stress

IV. CONCLUSION

The contamination of soil and water caused by changes in the environment, HMs and drought stress represent a serious threat for the public and food safety. The toxic effect of HMs under the drought stress and their distribution in plant organs by intracellular distribution need more experimental data. In the present paper, we evaluated the antioxidant status of the plants under the drought stress taking into account the concentration of HMs in order to assess and monitor levels of environmental pollution.

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