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FRACTAL ANALYSIS OF THE MODIFICATIONS INDUCED ON TOMATO PLANTS BY HEAVY METALS

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Abstract. The fractal analysis is most useful in characterizing the structure of branching trees, root of plants, leaves, membrane surface of cells and so on. The fundamental underlying principle in fractal geometry is self-similarity and scale invariance which is a principle in the development and growth of biological forms. The exponent of these properties is the fractal dimension which is direct measure of the relative degree of complexity of the figure. In this work we determined the fractal dimension of the tomato plants treated with zinc and cadmium. Our results showed that the fractal structure tomato leaves changed after the treatment with these heavy metals by comparison with the control ones.

Key words: Fractal dimension, Heavy metals, Tomato plant.

INTRODUCTION

Many biological objects like plants, leaves, roots, cells or sub cellular organelles display irregular shapes and discontinuous morphogenetic pattern in connection with their functional diversity and seem impossible to describe them rigorously or quantitatively using Euclidean geometry. Fern leaf is the familiar example in this domain. A quantitative approach to the size and shape of fern leaves has never been formulated [1]. The study about fern leaves showed that the shapes and fronds have fractal properties and fern fronds differ from one species to another.

Then concepts of fractal geometry are most useful in characterizing the structure of some irregular objects. Many physiological processes are influenced by the size [2]. G.B. West and coworkers [3] showed that the existence of fractal-like network endows life with an additional fourth spatial dimension. Natural selection has tended to maximize both metabolic capacity, by maximizing the scaling of exchange surface areas, and internal efficiency, by minimizing the scaling of transport distances and times.

The concept of a fractal is most often associated with geometrical objects satisfying two criteria: self-similarity and fractional dimensionality. Self-similarity means that an object is composed of sub-units that (statistically) resemble the structure of the whole object. The fractal dimension is a fractional quantity and it is a direct measure of the relative degree of complexity and roughness of the figure and it can never be greater than the Euclidian dimension of the space where the object is embedded (Benoit Mandelbrot, *The Fractal Geometry of Nature,* New York, 1975). Many authors used the fractal analysis to study the form of the different kind of plants and tissue [4]. J. R. Castrehon Pita and coworkers [5] measured the fractal dimension of an African plant that is widely cultivated as an ornamental, *Asparagus plumosus*. The authors showed in a quantitative way that this species is a fractal. Fractal geometry has been applied to describe various aspects connected with the complexity of plant morphology. Studies on the form for different kind of plants were reported in the literature [6-12].

The main objective of this study was to evaluate the impact of the treatment with zinc and cadmium on growth of tomato plants, using fractal analysis. In order to evaluate the change on tomato plants we determined the fractal dimension for untreated and treated tomato plant shoots.

MATERIAL AND METHOD

The tomato seeds (Buzau variety), were put into Petri dishes on double filter paper together with their treatment solution of different salts and 1% concentration where they were kept one week: $CdCl_2$, $ZnSO_4*7H_2O$ and $Cd(CH_3COO)_2*2\ H_2O$. After that they were washed and they continued to germinate into Petri dishes water. Germinated seeds were planted in pots at the Biophysics Laboratory where they developed in low conditions of temperature (16-20^{o}C). Then we sorted the following variants: 1 - untreated plants (control); 2 - treatment with $ZnSO_4*7H_2O$; 3- treatment with $Cd(CH_3COO)_2*2\ H_2O$.

After two months measurements on fractal dimension of the tomato plants were performed. To determine the fractal dimensions the modified box-counting method (BCM) method was used. HarFA soft

(Institute of Physical and Applied Chemistry, Brno University of Technology, Czech Republic) was utilized to study images of tomato plants. In HarFA is used a modification of traditional Box Counting Method. By this modification on obtain three fractal dimensions, which characterise properties of black plane DB, black-white border of black object DBW (and this information is the most interesting) and properties of white background DW. The fractal dimension is the slope of the straight line „Black&White" [13].

This method is, in our opinion, very easy to use and more accurate and can be applied in plant physiology.

RESULTS AND DISCUSSION

Figures 1 shows the untreated and treated tomato plants. These photos were prepared with the COREL PHOTO-PAINT 1 in order to use the HarFA soft to determine the fractal dimension. The fractal dimension for tomato plants is given in figure 2 and 3.

Our results showed that the average fractal dimension for untreated tomato plant is 1.4486 and for

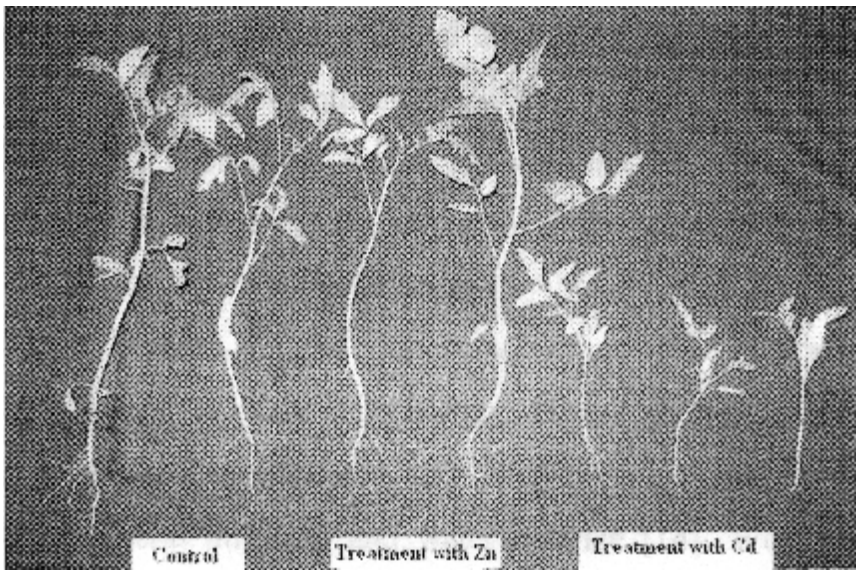

Figure 1. Tomato plants

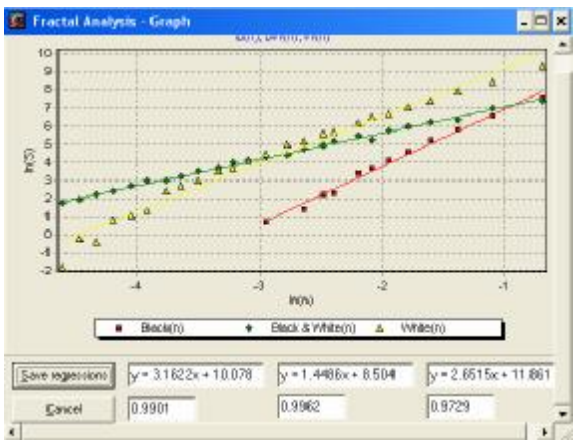

Figure 2. Fractal dimension for untreated plant

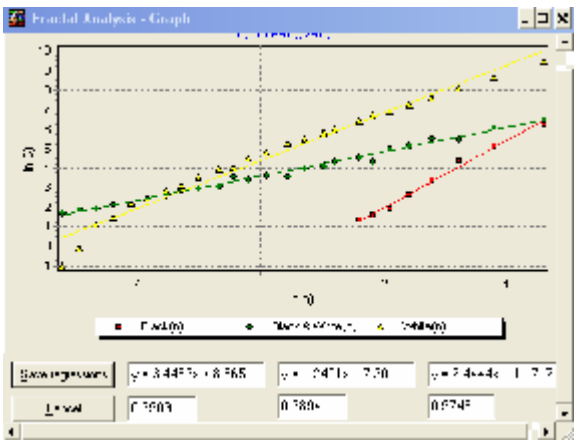

Figure 3. Fractal dimension for treated tomato plants with Cd

treated tomato plants with zinc it is 1.3254 and for treated tomato plants with cadmium it is 1.2401. Then these results showed that the treatment of the tomato plants with zinc and cadmium influences the responses of the plants to these stress factors.

CONCLUSIONS

In this work we pointed out the importance of concept of fractal structure in physiological characterization of plant morphology. Heavy metals induce a number of toxicity symptoms in plants e.g. choroids and blackening of root system it inhibits photosynthesis, upsets mineral nutrition and water balance [14]. We demonstrated that these heavy metals diminished the fractal dimension of the tomato plants. This means that heavy metals diminished both the plant growth and their capacity to develop complex leaves.

This work presents a morphological effect of Zn and Cd toxicity using a quantitative method of study, fractal analysis, with the scope to develop a strategy for heavy metal detoxification.

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