FRACTAL ANALYSIS OF THE MODIFICATIONS INDUCED ON TOMATO PLANT ROOTS BY TWO HEAVY METALS

ANALIZA FRACTALĂ A MODIFICĂRILOR INDUSE DE DOUĂ METALE GRELE RĂDĂCINILOR PLANTELOR DE TOMATE

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Abstract. *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. Many researchers have studied the complexity of the plant roots but there are few results due the influence of the rizosphere heterogeneity. The main objective of this study was to evaluate the impact of the treatment with cadmium and zinc on root architecture of the tomato plant, using fractal analysis. The seeds of tomatoes (Lycopersicon esculentum), were put into Petri dishes on double filter paper together with their treatment solution of 1% concentration from* $ZnSO_4*7H_2O$ *and* $Cd(CH_3COO)_2*2\ H_2O$*,and they were kept here for a week. After that they were planted in pots in the Biophysics Laboratory where they developed in low conditions of temperature (16-20*^{0}*C). After 6 weeks the measurements on fractal dimensions for tomato roots were performed using HarFA software. Our results showed that Zn produces an increase of lateral roots and their fractal dimensions, but Cd produces a strong decrease of the tomato roots.*

Rezumat. *Numeroase obiecte ca plante, frunze, rădăcini, celule sau organite celulare prezintă forme neregulate şi aspecte morfogenetice discontinue legate de funţionalitatea diversă şi pare imposibilă descrierea lor cu geometria Euclidiană. Complexitatea rădăcinii plantelor a fost studiată de mulţi cercetători dar sunt puţine rezultate datorită influenţei heterogenităţii rizosferei. Obiectivul acestui studiu este de a evalua impactul tratamentului cu cadmiu şi zinc asupra arhitecturii rădăcinii plantelor de tomate. Seminţele de tomate (Lycopersicon esculentum) au fost puse în sticle Petri cu hârtie de filtru şi soluţia de tratament de concentraţie de 1% de* $ZnSO_4*7H_2O$ *and* $Cd(CH_3COO)_2*2\ H_2O$ *unde au fost ţinute timp de o săptămână. Apoi seminţele au fost plantate în ghivece la laboratorul de Biofizică unde s-au dezvoltat în condiţii de temperatură joasă (18-20*^{0}*C). După 6 săptămâni au fost realizate măsurătorile privind dimensiunea fractală a rădăcinilor folosind programul HarFA. Rezultatele noastre au arătat că Zn produce o creştere a rădăcinilor laterale şi a dimensiunii fractale a acestora pe când Cd produce o puternică reducere a rădăcinii.*

INTRODUCTION

The ontogenetic development of plant root systems involves an increase both in size and in complexity. The complexity of root systems was of great interest for scientists for a long time but there are few results due the influence of the rizosphere heterogeneity.

The principles of fractal geometry seem appropriate for the description of root systems because the repetitive branching of roots leads to a certain degree of self-symmetry and such self-similarity is a fundamental characteristic of fractal objects (1-5), (9), (11).

The character of the distribution of plant roots in the soil is similar with to the fractal nature of the arteries and the veins or of the bronchi in the lung tissues, which uses with highest efficiency a certain volume with minimal cost.

It has been demonstrated that a real plant root is a fractal object; the problem is to choose an efficient method for determining the fractal dimension of larger root systems.

By comparing the fractal dimension of a certain plant to a wide range of external conditions it will be possible to determine how the values of fractal dimension reflect differences among root systems.

The main objective of this study was to evaluate the impact of the treatment with cadmium and zinc on root architecture of the tomato plant, using fractal analysis.

MATERIAL AND METHODS

The seeds of tomatoes (*Lycopersicon esculentum*), were put into Petri dishes on double filter paper together with their treatment solution of 1% concentration from $ZnSO_4$*7H_2O and $Cd(CH_3COO)_2$*2 H_2O,and they were kept here for a week.

After that they were planted in pots in the Biophysics Laboratory where they developed in low conditions of temperature (16-20^{0}C). Eshel also used tomato plant to study the root plant system is much used in research After 6 weeks, we performed the measurements on fractal dimensions for tomato roots, using HarFA software.

We sorted the following 3 variants:

1. M – control plants
2. Zn - treatment with $ZnSO_4$*7H_2O
3. Cd - treatment with $Cd(CH_3COO)_2$*2 H_2O

For analysis, the plants from the soil were extracted, washed and the root were cut from the shoot. Then we make many photos of the root with a Canon camera. These photos were prepared with the COREL PHOTO-PAINT 1 in order to use the HarFA soft to determine the fractal dimension. 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" (12).

RESULTS AND DISCUSSIONS

Some roots of the tomato plants treated with the Zn and Cd obtained with a Canon camera are given in figure 1.

From this figure we can see that the tomato plant roots treated with Zn are developed, especially the lateral roots. By contrary, the tomato plant roots treated with Cd are undeveloped, as a consequence, very small.

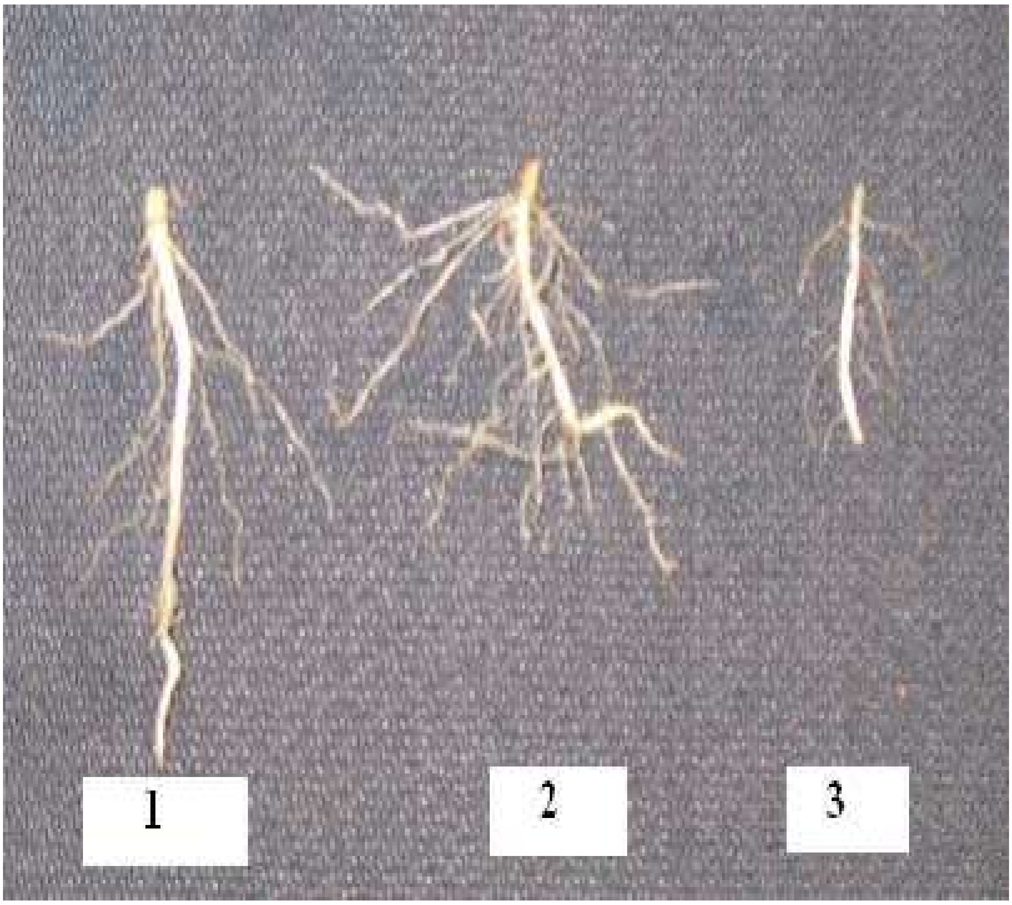

Fig.1 – Tomato plant roots

The fractal dimension for these plant roots are given in figures 2, 3 and 4.

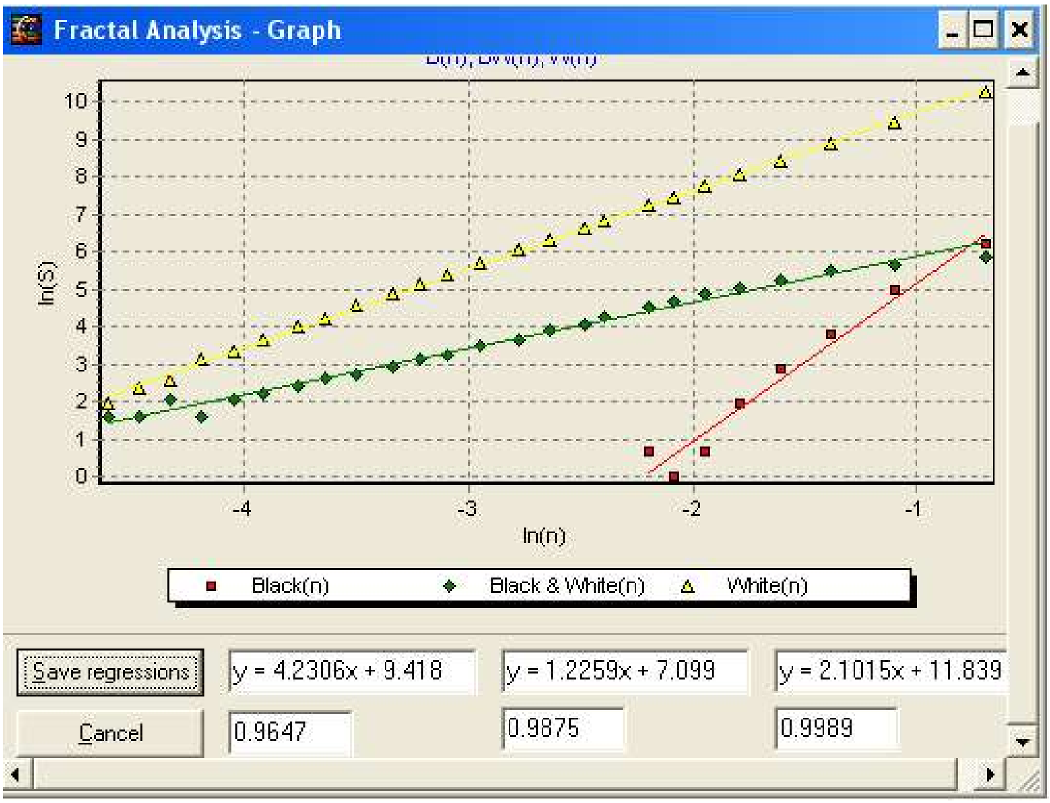

Fig.2 – Fractal dimension for tomato roots (control)

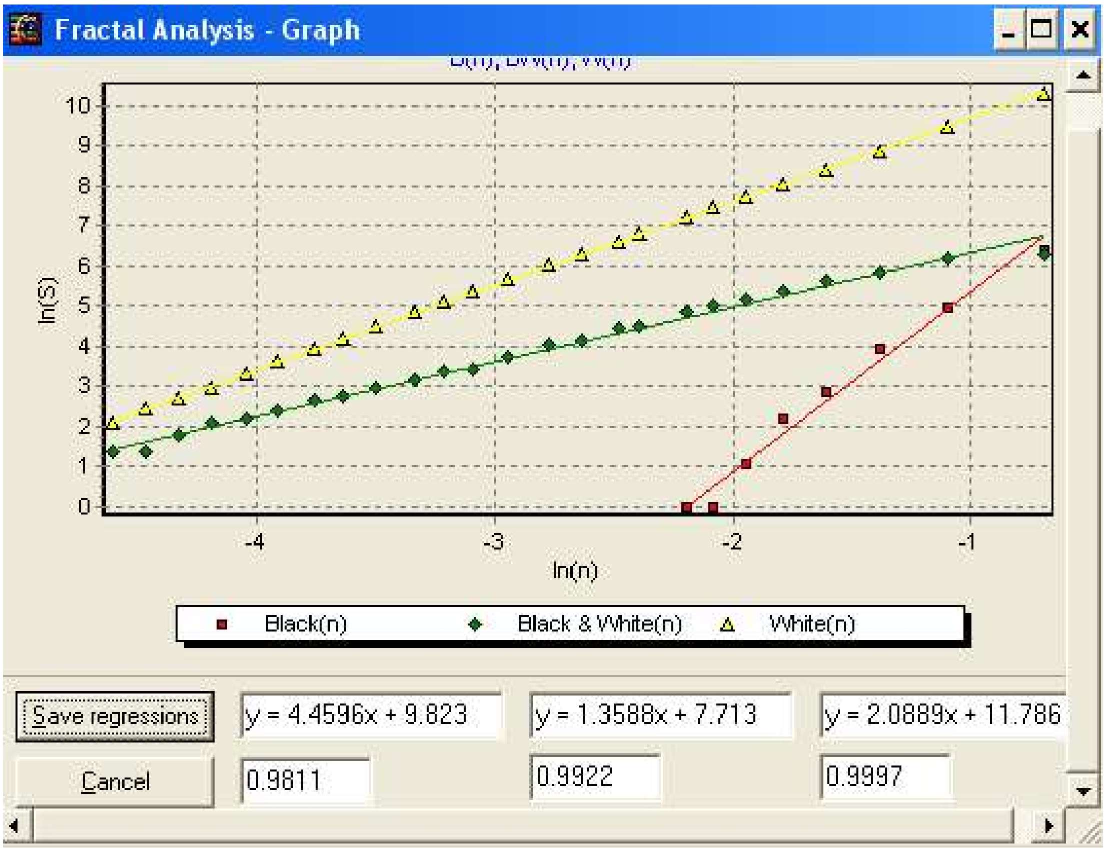

Fig.3 – Fractal dimension for tomato roots (treatment with Zn)

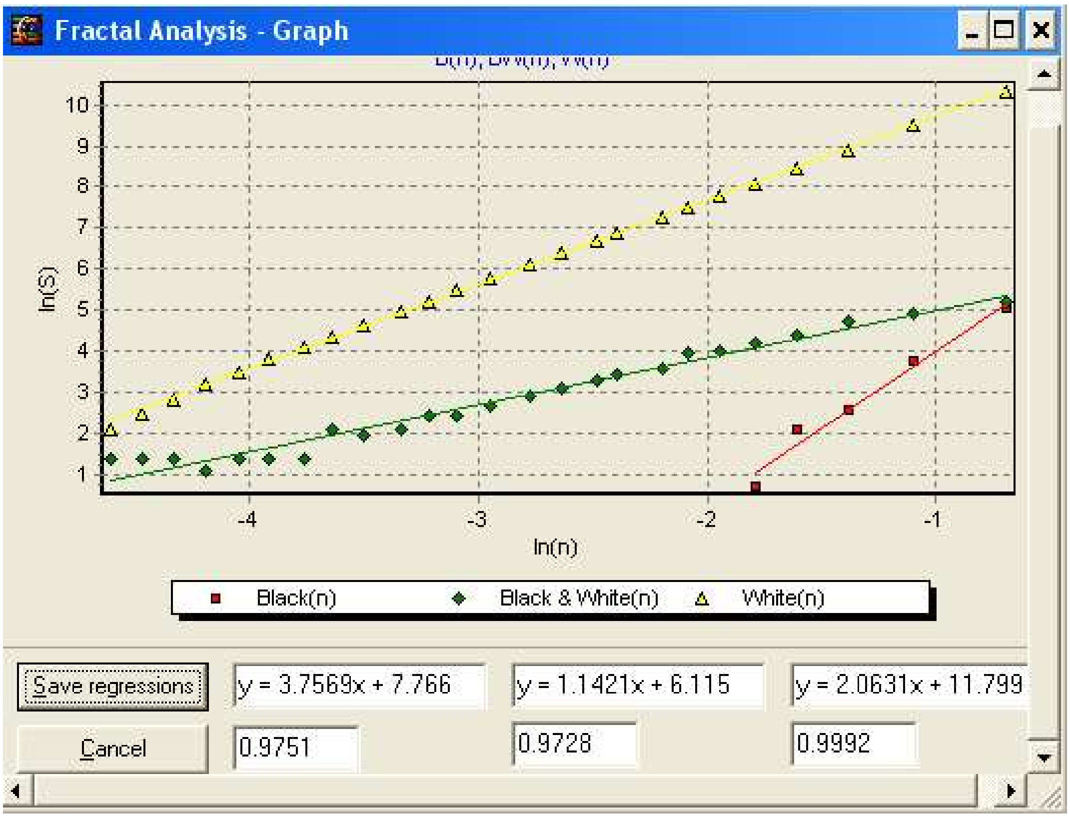

Fig.4 – Fractal dimension for tomato roots (treatment with Cd)

From these diagrams we can see that the fractal dimension for control plant root is 1,2259, it increases for Zn at 1,3588 and decreases for Cd at 1,1421.

These results confirm other experimental results about Zn and Cd effects on plant growth. This means that Zn have not effect the plant growth but it amplifies the root structure by numorous lateral roots. On the other hand Cd reduces both the plant height, the content of photosynthetic pigments and the shape and the structure of plant root (6-8), (10).

CONCLUSIONS

These results showed that the treatment of the tomato plant with these heavy metals modifies the fractal dimension of the roots.

Due the fact that the fractal dimension is a direct measure of the relative degree of complexity of the figure, we can conclude that these chemical compounds influence the root architecture and then modifies the root contribution to the water transport in plant and plant growth.

Therefore, the fractal dimension serves as a quantitative descriptor of the complex nature of the root system architecture.

REFERENCES

1. **Akasaka Y., Mii M, Daimon H, 1998** - *Morphological alterations and root nodule formation in Agrobacterium rhizogenas-mediated transgenic hairy roots of peanut (Arachis hypogaea L.).* Annals of Botany, 81 (2), 355-362
2. **Berntson GM**, **1994** - *Root systems and fractals: how reliable are calculations of fractal dimensions*. Annals of botany, 73 (3), 281-284
3. **Campbell R.D.**, **1996** - *Describing the shape of fern leaves: a fractal geometrical approach.* Acta Biotheoretica, 44, 119-126
4. **Eshel A**, **1998** - *On the fractal dimensions of a root system*. Plant Cell and Environment, 21 (2), 247-251
5. **Nielsen KL, Lynch JP, Weiss HN**, **1997** - *Fractal geometry of bean root systems: Correlations between spatial and fractal dimension*. American Journal of Botany**,** 84 (1), 26-33
6. **Oancea S.**, **2006** - *Fractal analysis of the root architecture for tomato plants treated with cadmium.* Lucrări ştiinţifice, Univ. de Stiinţe Agricole şi Medicină Veterinară Iaşi*,* Agronomie, 49, 246-250
7. **Oancea S., Foca N., Airinei A., 2005** - *Effects of heavy metals on plant growth and photosynthetic activity.* Analele Univ. Al. I. Cuza, Tom I, s, Biofizica, Fizică medicală şi Fizica mediului, 107-110
8. **Oancea S**., **Foca N., Airinei A., 2007** - *Phytotoxic effect of some heavy metals on tomato plant growth.* Lucrări ştiinţifice, Univ. Agrară de Stat din Moldova, Facultatea de Horticultură, Chişinău, 15 (3), 470-474
9. **Pita J.R.C., Galan A.S., Garcia R.C., 2002** - *Fractal dimension and self-similarity in Asparagus plumosus.* Fractals, 10(4), 429-434
10. **Sandalio L.M., Dalurzo H.C., Gómez M., Romero-Puertas M.C., del Río L.A., 2001** - *Cadmium-induced changes in the growth and oxidative metabolism of pea plants.* Journal of Experimental Botany, 52 (364), 2115-2126
11. **Tatsumi J., Yamauchi A., Kono Y., 1989** - *Fractal analysis of plant-root systems.* Annals of Botany, 64 (5), 499-503
12. **Zmeškal O., Veselý M., Nežádal M., Buchníček M., 2001** - *Fractal Analysis of Image Structures, HarFA* - Harmonic and Fractal Image Analysis, 3 – 5