THE FRACTAL DIMENSION AS A MEASURE OF THE CORN ROOT CHANGE TO THE NICKEL ACTION

DIMENSIUNEA FRACTALĂ CA MĂSURĂ A MODIFICĂRII RĂDĂCINII DE PORUMB LA ACȚIUNEA NICHELULUI

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Abstract. *The main objective of this study was to evaluate the impact of the treatment with nickel on growth of corn roots (Zea mays L.), using fractal analysis. In order to evaluate the change on root plants we determined the fractal dimension for untreated and treated corn plant roots. Seeds of corn were put into Petri dishes on double filter paper together with two solutions of* $NiCl_2*6H_2O$ *and they were kept here for four days. The germinated seeds were planted in soil where they continued to growth. After two weeks the root plants have been collected and the fractal analysis was performed. Our results demonstrated that the fractal structure of corn roots changed after the treatment with nickel. We confirm the fact that* Ni^{2+} *is a toxic ion that decreased the plant capacity to develop complex roots and the fractal analysis is a useful method to characterize the structure of plant roots.*
Key words*: root system, fractal analysis*

Rezumat. *Obiectivul principal al acestei lucrări este de a evalua impactul tratamentului cu nichel în creşterea rădăcinilor plantelor de porumb (Zea mays L.), folosind analiza fractală. Pentru a evalua modificările rădăcinilor plantelor, am determinat dimensiunea fractală a plantelor tratate şi a celor netratate. Semințele de porumb au fost puse la germinat în sticle Petri pe hârtie de filtru dublă şi cu două concentrații de* $NiCl_2*6H_2O$ *unde au fost ținute patru zile. Semințele germinate au fost plantate apoi în sol unde au continuat să crească. După două saptamâni au fost colectate rădăcinile şi s-a efectuat analiza fractală. Rezultatele arată că rădăcinile plantelor s-au modificat după tratamentul cu nichel prin comparație cu martorul. Noi confirmăm astfel că* Ni^{2+} *este un ion toxic care scade capacitatea plantelor de a dezvolta rădăcini complexe şi că analiza fractală este o metodă utilă pentru caracterizarea structurii rădăcinii plantelor.*
Cuvinte cheie: *sistemul radicular, analiza fractală*

INTRODUCTION

Nickel is considered one of the most abundant heavy metal pollutants of the environment. On the other hand, nickel is one of essential micronutrients for plants growth, the concentration of nickel required by vegetal tissues is of maximum 0,1 mg/L.

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The high concentrations of nickel (Ni) have deleterious effects on plant growth and metabolism, and produce visible effects of toxicity. The general effects associated with Ni toxicity in plants include inhibition of germination, reduced shoot and root growth, low development of branching system, deformation of the different plant segments, decrease of biomass, mitotic disturbances to root tip (Ahmad *et al.*, 2011).

The complexity of the plant roots has been studied by many researchers but there are few results due the influence of the rizosphere heterogeneity (Akasaka *et al.*,1998; Berntson, 1994; Campbell, 1996; Eshel, 1998; Melniciuc Puică *et al.*, 2006; Nielsen *et al.,* 1997; Oancea, 2006; Puzon, 2005). Root growth is related to the consumption of water and nutrients of plants and it directly take the effect of environmental change. By exploring different spatial niches, plants with contrasting root architecture may reduce the extent of competition among neighboring root systems. Root complexity has been difficult to comprehend using simple Euclidean methods. The main objective of this study was to evaluate the impact of the treatment with nickel on growth of corn roots, using fractal analysis.

MATERIAL AND METHOD

To study the effect of nickel on root growth, two concentrations of $NiCl_2*6H_2O$ have been prepared and we sorted the following variants:

1 - control;

2 – solution of 0.25% $NiCl_2*6H_2O$;

3 - solution of 0.5% $NiCl_2*6H_2O$

Generally, regarding chemical compound toxicity, researchers used such a range of dose just a 2x difference in concentration (Masih J.and Bhadauria V., 2010).

The experiments were conducted in the Biophysics Department Laboratory of the University of Agricultural Sciences and Veterinary Medicine Iasi (Foca. *et al.,* 2004), (Oancea S. et al., 2005). As a biological material we used corn (*Zea mays* L.), the most widely used cereal in our country. 100 seeds of corn were put into Petri dishes on double filter paper together with 20 mL treatment solution. Here the seeds were kept in dark at the optimal temperature (23^0C) for 4 days. After that the germinated seed were planted in soil in the our laboratory (fig. 1), where they developed for two weeks. For fractal analysis the plants were extracted from the soil, washed and the root were cut from the shoot. Then we make many photos of the root with a Canon camera (fig. 2).There are many other methods to determine the fractal dimension (Box Counting method, Yardstick method, Mass-Dimension Method, Perimeter–Area Method, Slit-Island Method, Asymptotic fractal formulas etc.). The photos were prepared in order to use the HarFA soft to determine the fractal dimension. We prepared the black and white images of the painting using the Digital Image Processing with Matlab. In Thresholding procedure a grey scale image is turned into a binary (black and white) image by first choosing a grey level T in the original image, and then turning every pixel black or white according to whether its grey value is greater than or less than T. The grey images of the coloured paintings have been processed also in Matlab.

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” (Zmeškal et al., 2001).

Fig. 1 – The corn plant

Fig. 2 – The corn roots

RESULTS AND DISCUSSION

For the last root from the figure 2 we obtain the results given in the graph from fig. 3.

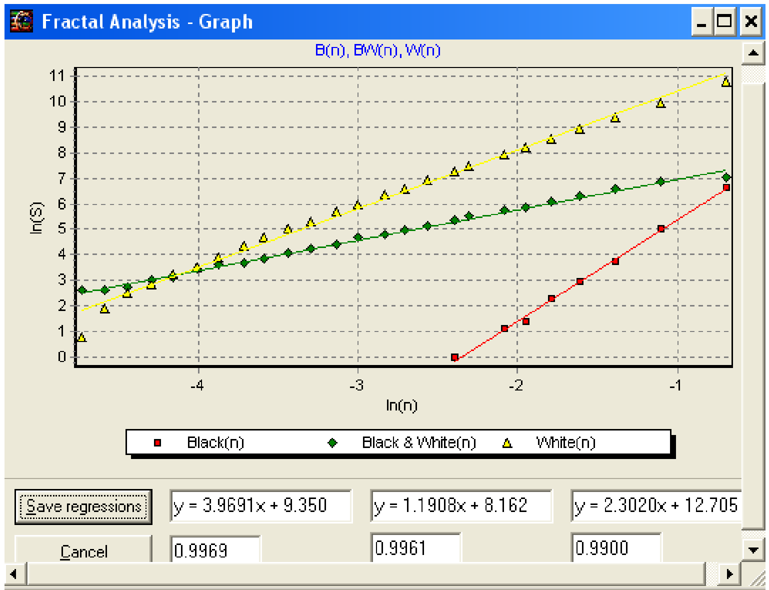

Fig. 3 – The graph for fractal dimension of the treated plants with 0.25 concentration $NiCl_2*6H_2O$

In figure 4 the mean values of the fractal dimension for plantlets are presented.

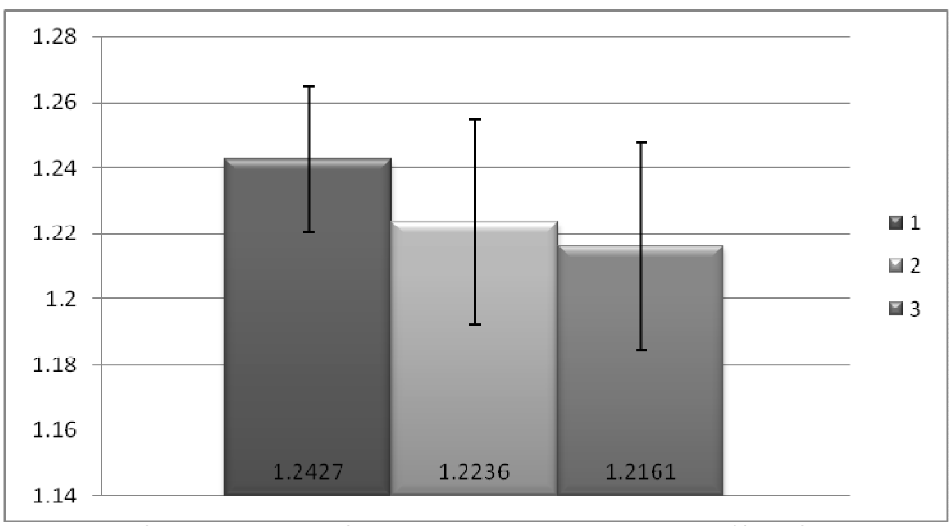

Fig. 4 – The fractal dimension of the plantlet roots (Error bars are 95% confidence intervals for n=5, Oancea, 2007)

The fractal analysis of the roots showed that the mean fractal dimension decreases from 1.2427 (in the case of the control corn roots) to 1.2161 (in the case of the treatment with 0.5 concentration of $NiCl_2*6H_2O$. These values sign up a straight line with a good correlation R- squared factor of 0.94. This result showed that the treatment of the corn plant with this chemical compound decreases the fractal dimension of the roots and the root complexity, contributing to a poor water transport in plant. Comparing these results with direct observations from figure 2 we can see that the fractal dimension is found to be correlated with root topology and root architecture.

CONCLUSIONS

From biological point of view, our results prove that plantlets treated with $NiCl_2*6H_2O$ show significant toxicity symptoms. However, the plantlets are able to cope with chemical stress due to a high capacity for change and adaptability.

In this work we pointed out the importance of concept of fractal structure in physiological characterization of root architecture. Our results demonstrated that the fractal structure of corn roots decreased after the treatment with nickel. Due the fact that the fractal dimension is a direct measure of the relative degree of complexity of the figure, we confirm the fact that Ni^{2+} is a toxic ion that decreased the plant capacity to develop complex roots.

We determined the planar fractal dimension of the roots from the above mentioned photos which can be connected with the other morphological changes in the root system.

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