RESPONSE OF TOMATO PLANTS UNDER ALUMINUM STRESS

Servilia OANCEA[1], N. FOCA[2], A. AIRINEI[3]

[1]University of Agricultural Science and Veterinary Medicine, Biophysics Department, Iasi, Romania
e-mail: lioancea@univagro-iasi.ro

[2]Technical University "Gh. Asachi", Faculty of Industrial Chemistry, Iasi, Romania

[3]Institute of Macromolecular Chemistry "P. Poni", Iasi, Romania
e-mail: airineia@icmpp.ro

Aluminum has been recognized as a toxic element for plant growth and a great number of studies have attempted to determine the toxic concentration of aluminum for different species. Despite decades of intensive research, the primary cause underlying the Al toxicity syndrome in plants has not been elucidated, even though the interaction between Al and Ca^{2+} is the strongest possibility. The celular mechanism of Al toxicity and tolerance in plant is another not yet elucidated problem. Phytotoxicity of aluminum is characterized by an inhibition of root elongation, but the mechanisms primarily responsible are not well understood. In this work we present our results on response of tomato plants under aluminum stress. In order to study the effects of aluminum cations on tomato plant development, we treated the plants with solutions of m/1000 concentration from four salts which contain aluminum. We monitored the dynamics of germination and the plant growth and then we performed measurements on biologic parameters and photosynthetic activity. Our results showed that the dynamic of germination, shoot length, biomass, and photosynthetic activity have been affected by aluminum treatment. Tomato plants treated with solutions of different salts which contain Al^{3+} responded in a different manner to this cation. Therefore the degree of germination was higher for untreated seeds than the treated ones; the effects of aluminum on roots resulted in strong inhibition, and structure damage, the most effect being for treatment with $KAl(SO_4)_2*12H_2O$ and the minimal effect being for $NH_4Al(SO_4)_2*12H_2O$. The same effect we can observe for biomass of tomato plants after two month and for content of photosynthetic pigment.

***Keywords**: aluminum cations, tomato plants, photosynthetivc pigments.*

Approximately 40–50% of the world's potentially arable soils are acidic. Aluminum (Al) toxicity has been recognized as one of the most important limiting factors of plant productivity on acidic soils. Afterwards Al toxicity was considered

to be one of the major factors of low rice productivity in acid upland and lowland acid sulfate soils. The molecular mechanism of Al toxicity and tolerance in plant is another not yet elucidated problem [2]. Phytotoxicity of aluminum is characterized by an inhibition of root elongation, but the mechanisms primarily responsible are not well understood. The view that the primary target of Al at cellular level might the plasma membrane was reported by many researchers. Al toxicity syndrome in plants has not been elucidated, even though the interaction between Al and Ca^{2+} is the strongest possibility. Zhang and coworkers [9] used the pollen tube as a suitable system to test interaction between Al and Ca ions due the fact that the pollen germination and tube growth are mediated by Ca^{2+} ions and are sensitive to Al. The authors investigated how Al and other known blockers of Ca^{2+} permeable channels (trivalent ions as La, Gd and nifedipine) influence pollen of an Australian native species. Therefore the inhibition of pollen germination by these cations could result from inhibition of Ca^{2+} influx into pollen grains, a process essential for pollen germination. The authors suggest that the Al interactions with the cell wall, in particular of the cell wall Ca^{2+} ions cross-linking the pectin molecules, may be the mechanism underlying pollen tube bursting. Rice (*Oryza sativa*) is one of the most Al-tolerant species among the cereal crops with a characteristic of forming iron plaque on its root surfaces. It has been proposed that the presence of iron plaque may act as a barrier, buffer or something else to reduce the uptake of potentially phytotoxic metals and metalloids into plant tissues. Rong Fu Chen and coworkers' study [1] determined the effects of root surface iron plaque on Al translocation, accumulation and the change of physiological responses under Al stress in rice in the presence of iron plaque. The authors carried out measurements on plant biomass, concentrations of metals and organic acid. Secretion of organic acid from plant roots when subjected to Al stress is considered as an important mechanism for plants to achieve high tolerance to Al. Al causes a significant decrease in both the viscous and elastic extensibility of cell wall of the root apices. Wang and Yang [8] investigated the effect of NO on *Cassia tora L*. plants exposed to aluminum. Plants pre-treated with sodium nitroprusside (SNP), an NO donor and exposed to 10 μM Al treatment for 24 h exhibited significantly greater root elongation as compared with the plants without SNP treatment. The NO-promoted root elongation was correlated with a decrease in Al accumulation in root apexes. These effects were confirmed by the histochemical staining for the detection of peroxidation of lipids and loss of membrane integrity in roots. Their results indicate that NO plays an important role in protecting the plants. However, it is unclear whether these events caused by Al are the result or cause of Al-induced inhibition of root elongation. In this work we present our results on response of tomato plants under aluminum stress.

MATERIAL AND METHOD

The seeds of *Licopersicum esculentum,* Buzau variety, were put into Petri dishes on double filter paper together with their treatment solution of different salts and m/1000 concentration where they were kept two days.

We sorted the following variants: 1-control; 2- $Al_2(SO_4)_3*18H_2O$; 3- $NH_4Al(SO_4)_2*12H_2O$; 4- $KAl(SO_4)_2*12H_2O$; 5- $AlCl_3*6H_2O$

After that the seeds were washed and they continued to germinate into Petri dishes water. We monitored the dynamics of the plant germination during 10 days. Germinated seeds were planted in pots at the Biophysics Laboratory where they developed in low conditions of temperature (16-20^{0}C). After two months measurements on growth and photosynthetic activity was performed. The measurements of the composition of photosynthetic pigments for tomato plants were performed with a spectrophotometer. For pigment analysis were measured 1 g of fresh leaf tissue and were cut the leaves into small pieces (about 1 mm wide). The pigments were extracted by grinding in a mortar and pestle for 5 minutes. Afterwards the extract was filtrated and transferred to 100 ml acetone. The pigment analysis was performed with the spectrophotometer SPECORD 200 from Analytik Iena, immediately after the solutions were prepared. The content of the photosynthetic pigments was calculated with the following formula from [6].

RESULTS AND DISCUSSION

The dynamics of plant germination is presented in figure 1 and the dimension of the plant roots after 9 days is presented in figure 2.

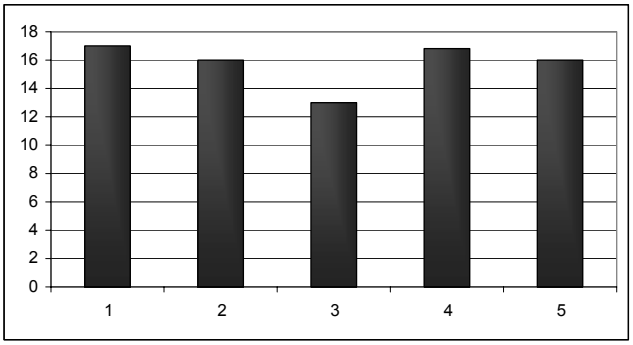

Figure 1. **The number of germinated seeds after one week**

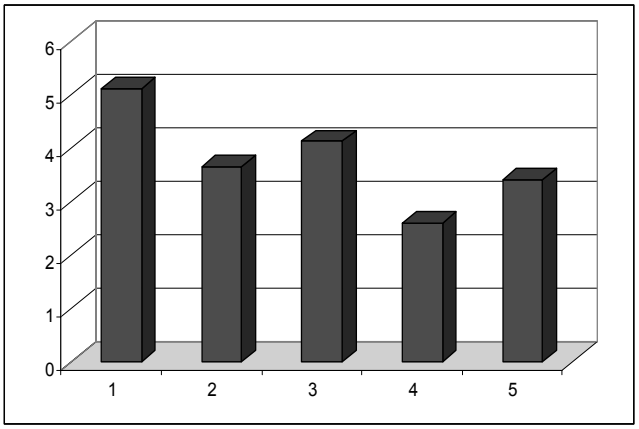

Figure 2. **The dimension of the plant roots after 9 days**

Results of the measurements on the plant biomass are given in figure 3.

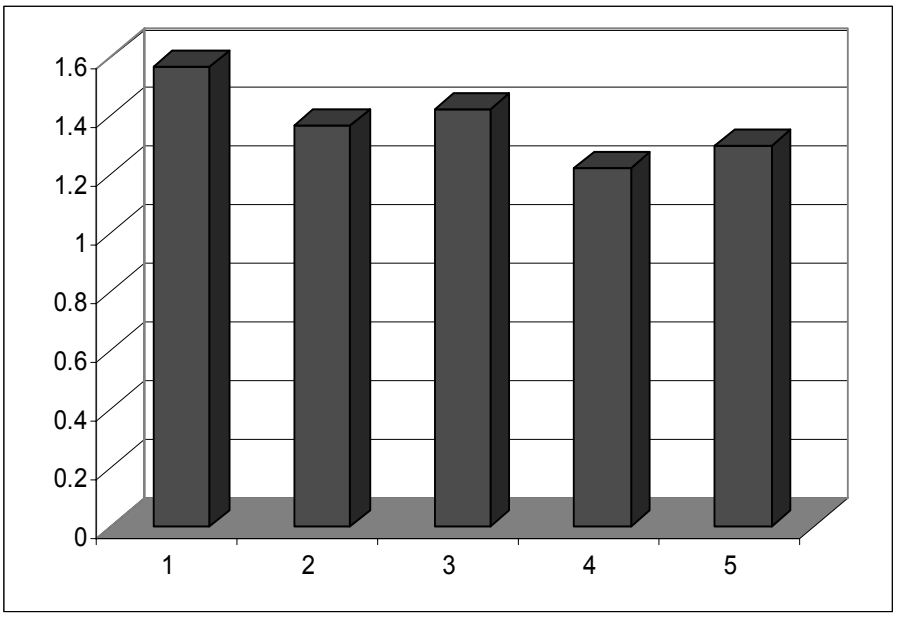

Figure 3. **The biomass of tomato plants**

In figure 4 are presented spectra of acetonic extract from tomato leaves treated with these four solutions and the control plants.

The content of photosynthetic pigments for the five studied variants is presented in the figure 5.

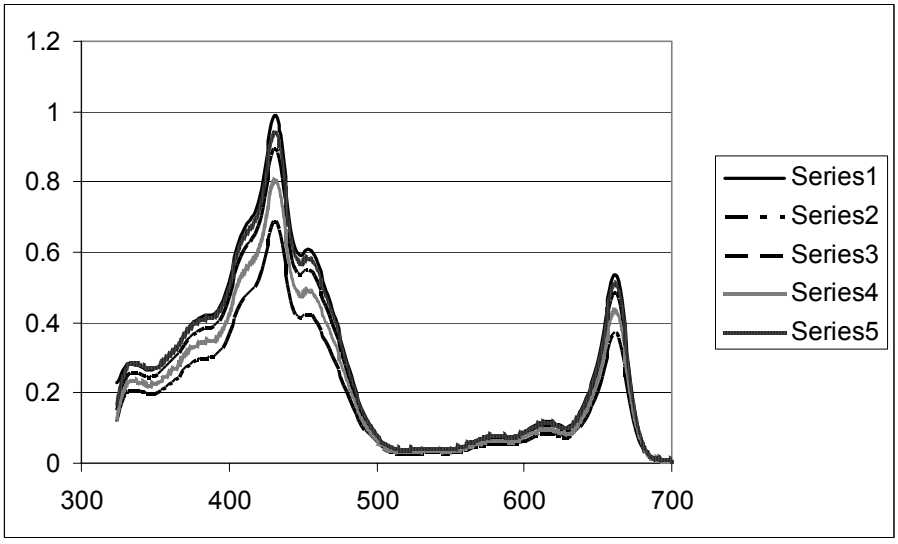

Figure 4. **The spectra of acetonic extract from tomato leaves**

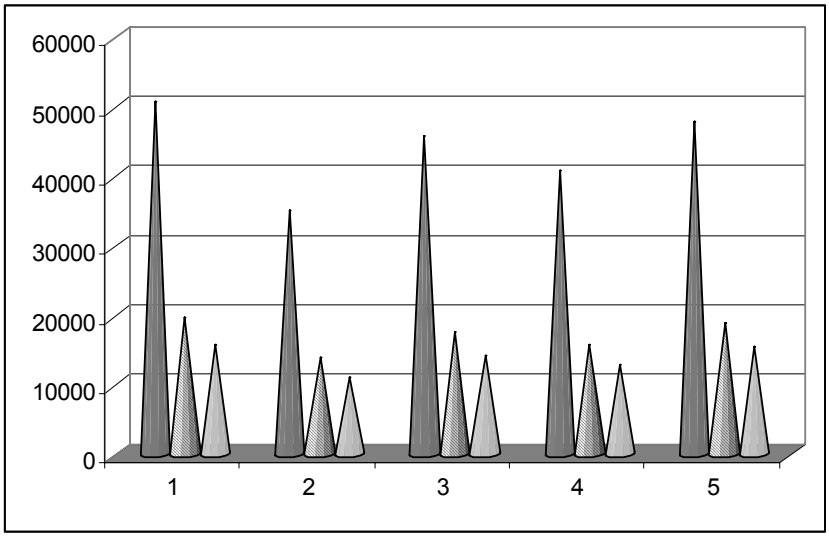

Figure 5. **The content of chlorophyll a, chlorophyll b and carotenoids from tomato plants**

Our measurements showed that the degree of germination was higher for untreated seeds than the treated ones. The effects of aluminum on roots resulted in strong inhibition, and structure damage, the most effect being for treatment with $KAl(SO_4)_2*12H_2O$ and the minimal effect being for $NH_4Al(SO_4)_2*12H_2O$. We suggest that N from $NH_4Al(SO_4)_2*12H_2O$ diminished the toxic effect of Al. The same effect we can see for the biomass of plants. The dimension of the plant roots and the biomass of plants are good correlated with a correlation coefficient r = 0.96. Our results are concordant with results of other authors. Results of Ma and coworkers [4] suggest that the Al-dependent changes in the cell wall viscosity and elasticity are involved in the inhibition of root growth. It seems that Al interacts with multiple sites of the root cells including cell wall, plasma membrane and symplasm.

Al effects on root growth have been attributed to putative interaction between Al ions and the cytoskeleton, since Al^{3+} ions were shown to affect micro tubular polymerization and dynamics in vitro [7]. The cytoskeleton of maize roots was reorganized and stabilized in a cell-specific manner in response to Al exposure. These cytoskeletal changes caused by Al^{3+} ions have been observed in the rapidly dividing and elongating cells of the root rather than the mature root tissues. Meriga and coworkers [5] reported that Al can cause DNA damage. Increasing evidence suggests that in both, animal and plants, Al toxicity is related to an increased production of toxic oxygen free radicals. Enhanced production of oxygen free radicals is responsible for changes in activities of antioxidant enzymes like peroxidase. Al induced DNA damage was presumed to be a consequence of direct attack of oxygen free radicals on DNA strands.

Our measurements showed a decline of physiological and biochemical activities as well as of the function of plants for Al^{3+} treatment.

From figure 5 we can see that the content of pigment is higher for control plants than the treated ones. Through the treatments, the content of pigments is higher for plants treated with $NH_4Al(SO_4)_2*12H_2O$ and, contrary to expectations, for $AlCl_3*6H_2O$ than the other treatments.

CONCLUSIONS

Our results showed that the dynamic of germination, shoot length, biomass, and photosynthetic activity have been affected by aluminum treatment. Tomato plants treated with solutions of different salts which contain Al^{3+} responded in a different manner to these treatments.

We concluded that Al effects on plant growth are very important and we will keep analysing its effects on other studies that we will carry out. These studies have to include issues on bioavailability, solubilization and transport mechanisms.

Unfortunately, in this phase of the research, there have been no measurements taken about the transmission of aluminum to the roots, the leaves and the fruits of the plants and need to find new methods in order to predict the metal transfer from soil to plant [3].

REFERENCES

1. Chen R.F., Shen R.F., Gu P., Dong X.Y., Du C.W., Ma J.F., 2006 - *Response of Rice (Oryza sativa) with Root Surface Iron Plaque Under Aluminium Stress*, Annals of Botany, 98, p. 389–395.
2. Heim A., Brunner I., Frossard E., Luster J., 2003 **-** *Aluminum effects on Picea abies at low solution concentrations***,** Soil Science Society of America Journal*, 67(3),* p. 895-898
3. Krauss M., Wilcke W., Kobza J., Zech W., 2002 - *Predicting heavy metal transfer from soil to plant: potential use of Freundlich-type functions*, Journal of Plant Nutrition and Soil Science, 165, p. 3-8
4. Ma J.F., Shen R.,Nagao S., Tanimoto E., 2004 - *Aluminum Targets Elongating Cells by Reducing Cell Wall Extensibility in Wheat Roots***,** Plant & Cell Physiology, 45(5), p. 583-589
5. Meriga B., Reddy B.K., rao K.R., reddy L.A., Kishor P.B.K., 2004 **-** *Aluminium-induced production of oxygen radicals, lipid peroxidation and DNA damage in seedlings of rice (Oryza sativa)***,** Journal of Plant Physiology, 161(1), p, 63-68
6. Oancea S., Foca N., Airinei A., 2006 - *Some results of heavy metal effects on Capsicum Annuum development*, Lucrari stiintifice,Univ. de Stiinte Agricole si Medicina Veterinara Iasi*,* Agronomie, Vol 49, 251-255
7. Schwarzerova K., Zelenkova S., Nick P., Opatmy Z., 2002 - *Aluminum-Induced Rapid Changes in the Microtubular Cytoskeleton of Tobacco Cell Lines***,** Plant & Cell Physiology, 43(2), p. 207-216
8. Wang Y.S., Yang Z.M**.**, 2005 - *Nitric Oxide Reduces Aluminum Toxicity by Preventing Oxidative Stress in the Roots of Cassia tora L*., Plant Cell Physiol. 46(12), p.1915–1923
9. Zhang W.H., Rengel Z., Kuo J., Yan G., 1999 - *Aluminium Effects on Pollen Germination and Tube Growth of Chamelaucium uncinatum. A Comparison with Other* Ca^{2+} *Antagonists,* Annals of Botany*,* 84(4), p. 559-564