THE EFFECT OF ENVIRONMENTAL POLLUTION, ACIDIC RAINS, ALUMINIUM CONTAINING PACKAGING ON THE GROWTH OF WHEAT

Szabó-Nagy Andrea*, Véha Antal, Gyimes Ernő

Department of Food Engineering, Faculty of Engineering, University of Szeged 6725 Moszkvai krt 5-7, Szeged, Hungary, e-mail*: szna@mk.u-szeged.hu, telephon: +36-62-546528

Abstract

In the present work the solubility of the packaging aluminium foils was studied at acidic pH and a quite high amount of Al^{3+} ions. near 2500 ppm , was found in the solution on the surface of the foil. The measurment of Al content was made by inductively coupled plasma–mass spectrometry (ICP-MS). The toxicity of the trivalent Al form is a factor reducing plant growth and limiting crop productivity.

Significant difference was found in the phosphorus content, and the P translocation to the shoot was inhibited by Al. The Al content of root was one magnitude higher than in the shoot.

Key words: acidic rains, aluminium stress, phosphorus, winter wheat

INTRODUCTION

Unfortunatelly people often cause serious damages in the environment by the industrial and agricultural processes, nowadays packaging material cause heavy problems. Food packaging, post-use disposal (waste) and aluminium foil manufacturing increase environmental pollution, recently Al-foils are priority toxins in the United States and Germany, as well. Aluminium is the most frequent metal of the earth crust, but at alkaline, neutral or mildly acidic soils it occurs mainly as insoluble deposit, this form is biologically inactive. At acidic pH the solubility of the natural, bound aluminium-forms increase. Environmental problems such as some farming practices, industrial contaminations, acid rains increase the acidity of the soils leading to the mobilization of the Al. More than half of the world's potential arable lands are acidic and Al toxicity is a major factor limiting crop productivity.

Wheat (Triticum aestivum L.) is a staple food for more than one third of the world population. The effects of Al stress (0.1 mM Al) was followed on the growth of winter wheat (*Triticum aestivum* L. cv. Martonvásári-8) seedlings. Plants were grown in a complete nutrient solution with or without 0.1 mM Al addition, the growth of plants and Al content in the different plant parts were followed.

Significant difference was found in the phosphorus content, and the P translocation to the shoot was inhibited by Al. The Al content of root was one magnitude higher than in the shoot.

MATERIAL AND METHODS

The solubility of the packaging aluminium foil was studied at acidic pH using 3% acetic acid at 40 ^{o}C for 10 days. The Al content was determinated by inductively coupled plasma-mass spectrometry (IPC-MS).

Plant growth and element analysis

A nutrient solution (modified Hoagland) at pH= 4.5 containing 0.1 mM $AlCl_3$ was used to examine the effect of Al on winter wheat (*Triticum aestivum* L. cv. Martonvásári-8). Control plants were grown under Al free condition, P deficient plants were grown without phosphorus. Fifty seeds were then placed on plastic nets over plastic beakers, each containing 4 l of nutrient solution, and 4 replicate beakers were cultivated in the case of each treatment. The nutrient solution was changed twice a week. The seedlings were grown hydroponically under controlled condition for two weeks with a 12 h day-time illumination of 60 W m-2, day/ night temperatures were 23/18 ^{o}C, the relative humidity of the air was 85%.

The fresh and the dry weight of the root and shoot were measured, and N,P,K, Ca and Al content were determined after wet digestion. Nitrogen and phosphorus content was determined colorimetrically and the content of K, Ca and Al was measured by atomic absorption spectrofotometry described by Szabó-Nagy et al. 1987.

Isolation of Membrane vesicles and enzyme assay

Young roots were harvested, washed in cold distilled water and homogenized in 3x volumes of homogenization buffer, containing 250 mM sucrose, 5 mM EDTA, 50 mM Tris-MES buffer (pH 7.5). The 10 000-30000 g microsomal fraction (MF) was prepared and Mg^{2+}-ATPase activity was measured as described earlier (Szabó-Nagy et al. 1987,1992).

Background ATPase activity was measured in the presence of 0.1 mM EDTA, 0.1 mM $(NH4)_6Mo_7O_{24}$, 1 mM NaN_3, 3 mM ATP, 25 mM Tris-MES buffer (pH 6.0) with 0.015 mg protein (Szabó-Nagy et al. 1994).

Statistical analysis The fresh and the dry weight of the roots and shoots were measured as averages of 5 plants. The element concentrations are given as the mean of three replicate determination, replicates differed by less than 10%. Microsomal ATPase activities were determined from three independent series of plants, deviation between series was less, than 20 %.

RESULTS AND DISCUSSION

In our experiments it was found, that at acidic pH in the solution on the surface of the aluminium foils 2422 $\pm$ 148 ppm Al^{3+}-ion was found (3 parallel examination).

Our result support, that under acidic circumstances (acidic rains) a lot of Al^{3+} could be solved from aluminium containing waste, and it could be dangerous for biological systems.

The in vivo effects of ionic form of Al (0.1 mM, at pH 4.5) on the wheat growth and on the contents of some important element were followed, control plants were grown under Al-free conditions.

The weight of the roots was decreased (82 % of the control) by Al stress, but in the case of the shoots no significant changes were found after two weeks. The decreased root growth could be a consequence of Al-induced inhibition of the root elongation (Fig.1.).

The Al content of the roots was near one magnitude higher than that of the shoots in the Al treated plants, suggesting that the translocation of Al was hindered. Especially in the case of edible plants it is very important to know, which parts of the plants are effected by increased Al content under Al-stress conditions, since it could be dangerous in the foods and feeds.

No significant differences were found in the Potassium and Nitrogen content of the control and Al-treated plants, it varied between 95-104 % of the control, both in the case of the roots and the shoots. In the P and Ca content of the roots significant differences were found, caused by 0.1 mM Al-addition to the nutrient solution. P content was increased by 35%, Ca content was decreased by 26% (Fig.1).

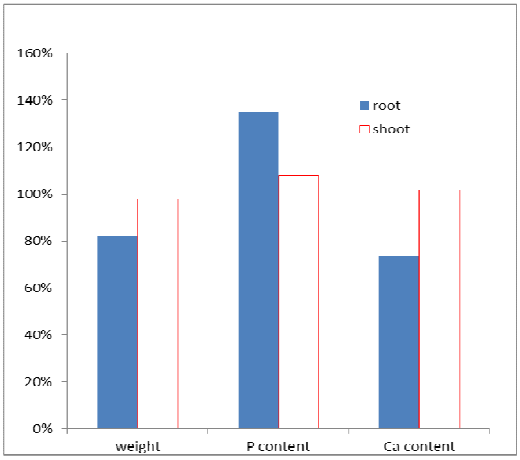


Fig.1. Comparison of the growth, P and Ca content of the control and Al-treated wheat plants (the results presented as a percentage of the control)

The precipitation of aluminium by phosphorus in the apoplast, and the accumulation of Al-P complex in the root, can explain the measured increased P level.

The Al-induced inhibition of Ca^{2+} uptake was found by Huang et al. (1992) in the Al-sensitive wheat, as well. Changes in ionic composition of wheat root indicate that the ionic uptake processes were affected by Al-stress. These results suggest that Al affects Ca^{2+} movement across the root plasmalemma, possibly via blockage of calcium channels and Ca^{2+}-influx. Root cell membrane, particularly of the root apex, seems to be a major target of Al toxicity.

The ionic form of Al cause growth retardation and injurious in the cells, it can be derived from the binding to phosphorus in different positions such as phospholipids in the membranes.

The root plasma membrane H^{+}-ATPase plays a central role in the ionic uptake processes.

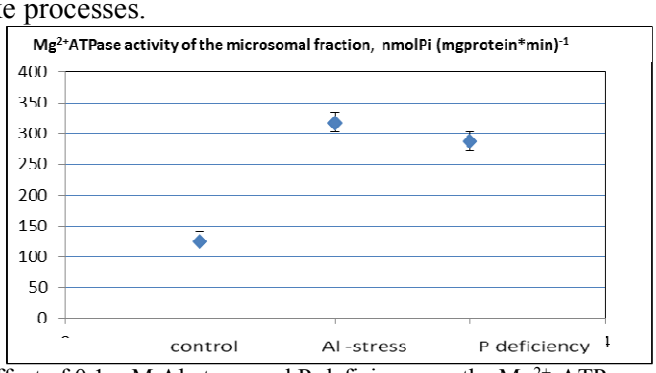
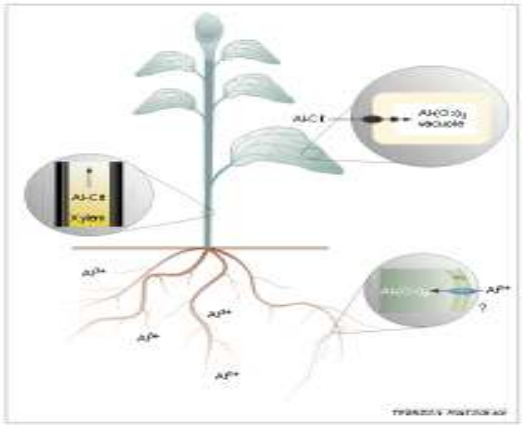


Fig. 2.The effect of 0.1 mM Al-stress and P-deficiency on the Mg^{2+}-ATPase activity of the microsomal fraction prepared from roots of wheat

The Mg^{2+}-ATPase activity of the microsomal fraction was significantly increased, it was more than two times higher both in Al stressed and in P deficient roots comparing to the controls. (Fig.2.). In MF some intracellular membranes and different enzymes attached to the membrane particles can be found, and they can cause the measured increase of the Mg^{2+}-ATPase activity, as well.

The Al induced changes may be related to different factors, such as phosphorus metabolism, as it was suggested by increased P content. Against higher P-level could be a shortage of the available P content. Increased Mg^{2+}-ATPase enzyme activity in the MF was observed in P deficient plants, as well this increase could be connected to an acid phoshatase induction (Szabó- Nagy et al. 1987, 1995). Acid phosphatases are widely distributed in plants, they have intra and extra cellular activity, and their roles are very important in P-metabolism, they increase the amount of the available inorganic phosphate or they play a role in signal transduction. However, acid phosphatase activity is increased by other stress factors, for example by salt and osmotic stress (Szabó-Nagy et al.1992., Szabó-Nagy & Erdei, 1995., Ehsanpour & Amini, 2013).



CONCLUSIONS

Food packaging and post-use disposal cause environmental pollution, recently aluminium foils are priority toxins. In our experiments 2500 ppm Al was released from the foil at acidic pH. The Al-stress is a very serious and growing problem all over the world, decreasing crop production in the last decades since the acidity of the soil is increasing. Some plant species and cultivars depending on their genetical inheritances, have evolved some mechanisms for detoxifying Al both internally and externally. There are some evidences, that Al detoxification and changes in phosphorus

metabolism has some connections. The Al stress caused retardation of root growth and an increase of Al and P content. It could be the part of the strategy: the insoluble Al-P complexes could reduce the toxic form of Al in wheat roots. The decreased Ca^{2+} content of the roots could be the result of the changes of the ionic uptake processes.

The microsomal enzyme activity, measured in the presence of Mg^{2+}ATP as a substrate, was more than two times higher in case of Al treated plants, than that of the control. Similar icrease of the activity was found under P deficiency, but this increase could be originated from other membrane fragments, or some loosely bound, inducible phosphatases in the fraction.

Under Al-stress Al can accumulate in the different plant parts, and the amount of valuable compounds can change, as well. These changes influence not only the quantity, but the quality of the food.

Acknowlegdements

Aluminium content of the samples was measured by inductively coupled plasma–mass spectrometry (icp-ms) by Attila Ördög and Irma Tari in the Department of Plant Biology, Faculty of Science and Informatics, University of Szeged.

REFERENCES

1. Ehsanpour A., Amini F., 2013, Effect of salt and drought stress on acid phosphatase activities in alfalfa (*Medicago sativa* L.) explants under *in vitro* culture. *African Journal of Biology* 1 (2), 120-121.
2. Huang J. W., Shaff J. E. Grunes D. L., Kochian L. V., 1992, Aluminum Effects on Calcium Fluxes at the Root Apex of Aluminum-Tolerant and Aluminum-Sensitive Wheat Cultivars. *Plant Physiology* 98 (1) 230-237.
3. Szabó-Nagy A., Oláh Z., L. Erdei L., 1987, Phosphatase induction in roots of winter wheat during adaptation to phosphorus deficiency. *Physiologia Plantarum*, 70. 544–552.
4. Szabó-Nagy A., Galbiba G., Erdei L., 1992, Induction of soluble phosphatases under ionic and non ionic osmotic stress in wheat. *J.Plant Physiol*. 140. 629-633.
5. Szabó-Nagy A., Erdei L., 1995, Phosphatase induction under stress conditions in wheat. in: Baluska F. et al.(eds) *Structure and Function of Roots*, 163-167.