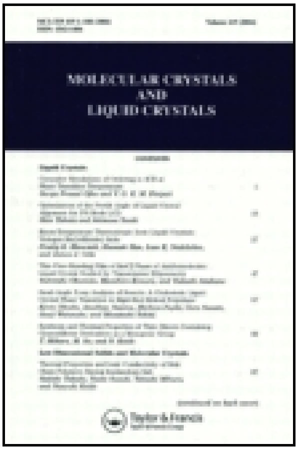

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GROWTH AND PHOTOSYNTHETIC ACTIVITY FOR TOMATO PLANTS TREATED WITH DIFFERENT CATIONS

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The effect of the treatment with nitrates on growth and photosynthesis for tomato plants (Lycopersicon esculentum) is presented. Tomato plants were grown in pots and treated with solution of nitrates. The experiments were carried out twice in a greenhouse of the University. Measurements for leaves number, height of plants and flowers number were performed. The content and composition of photosynthetic pigments were examined in the third leaf of tomato plants. Our results show that the tomato plants treated with $Mg(NO)_2$ and $Ca(NO)_2$ have a bigger content of the pigments but the tomato plants treated with $Ba(NO)_2$ are better developed than the control. The physiological significance of the modifications to the pigment composition induced by this treatment is discussed.

Keywords: aquacomplex; crop plants; nitrates; photosynthesis

INTRODUCTION

The effect of different chemical compound on growth of plants present much interest because, in crop plants, deficiency of an essential element may drastically reduce growth rate and yield [1–3]. Many authors examined the growth and the performance of photosynthetic apparatus of plants in

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connection with these chemical compounds. Carotenes especially have attracted much attention in recent years for their biological function [4,5].

The effect of different metallic ions in the hydrolysis of ATP is studied in [6] and the effect of copper on chlorophyll organization was examined in [7]. Copper was found to inhibit pigment accumulation and to retard chlorophyll integration into the photosystems. Another studies treat the subject of different methods for chemical fertilization or biochemical treatment with the intention to stimulate the crop. The problem appears when these chemical compounds are present in the fruit of these plants that are eaten by people. That implies new rapid method to determine the transfer of this chemical compounds from soil to the plant [8].

Little information on growth of plants and the mechanism of photosynthesis is available about the effects of the treatment with nitrates that contain different cations.

It is known that the bivalent metals Mg and Ca have the greatest importance in biological processes.

Calcium is a constituent of cell walls and is involved in production of new growing points and root tips. It acts as a base for neutralizing organic acids generated during the growing process and aids in carbohydrate translocation and nitrogen absorption. Indeed, calcium might be considered the bricks in plant assembly, without which cell manufacture and development would not occur.

Calcium deficiency symptoms appear in the meristem regions of leaves, stems, buds, and roots. Younger leaves are affected first and are usually deformed. In extreme cases, the growing tips die. The leaves of some plants hook downward and exhibit marginal necrosis. Roots on calcium-deficient plants are short and stubby. In tomatoes and peppers, a black leathery appearance develops on the blossom end of the fruit. In such cases, the fruit ceases to develop and eventually falls off. Ca is the only cation that generally is not toxic.

In what Mg is concerned it determines a growth in the content of root proteins and young sprouts. Magnesium is also essential for the metabolism of carbohydrates. Mg activates a series of enzymes like phosphatase, enolase, carboxilase, phosphorilase. It regulates uptake of the other essential elements, serves as a carrier of phosphate compounds throughout the plant, facilitates the translocation of carbohydrates and enhances the production of oils and fats. Magnesium deficiency is most prevalent on sandy coastal plain soils where the native magnesium content is low.

The effect of another bivalent element from this group, Ba, is less known. A review of the early literature summarizes the quantity of barium present in many plants. Many authors determined the barium content of a large number of food items, including dairy products, cereals, fruits and vegetables. Despite relatively high concentrations in soils, only a limited amount of barium accumulates in plants. Soluble barium compounds are capable of being transported through the environment and absorbed by organisms. Legumes actively take up barium. Barium can replace calcium in many physiological processes, and it affects nerve and muscle activity. Barium has been reported to inhibit growth and cellular processes in microorganisms. Little information on the adverse effects of barium on terrestrial plants has been found.

Other authors assumed that the presence of Ba stimulates the growth of some plants but this has not yet been confirmed. That is the reason that determined us to study some aspects linked with the growth of tomato plants treated with nitrates that contain cations of the second group that include Ba. We desire to publish this data especially because little is known about the effect of Ba on the development of tomato plants and flowers. Nitrates were chosen because these salts are often used for chemical fertilization. *Lycopersicon esculentum*, (tomato) was chosen because it is a plant that has been used for much research [9] and tomatoes concentrates soil barium.

MATERIALS AND METHODS

Tomato seeds (*Lycopersicon esculentum*) Buzau variety, were planted both in the University of Agronomy and Veterinary Medicine Iasi greenhouse and in the Biophysics laboratory and they were grown in pots. The tomatoes planted in the greenhouse were grown in optimal conditions while those planted in the laboratory were grown in sub-optimal conditions. We prepared three solutions with 5% concentration containing Mg, Ca, Ba cations: $Mg(NO_3)_2$, $Ca(NO_3)_2$, $Ba(NO_3)_2$. Six weeks after sowing we treated the plants separately with these solutions and we sorted the following samples:

1. Untreated solution
2. Treatment with $Mg(NO_3)_2$
3. Treatment with $Ca(NO_3)_2$
4. Treatment with $Ba(NO_3)_2$

In order to accomplish the goal of this experiment 60 ml solution were poured into the soil at the root of each plant. The procedure was performed once a week for three weeks in a row. A week after the end of the treatment the analysis of the growth and the photosynthetic activity was performed.

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 a spectrophotometer SPECORD M 42, immediately after the solutions were prepared.

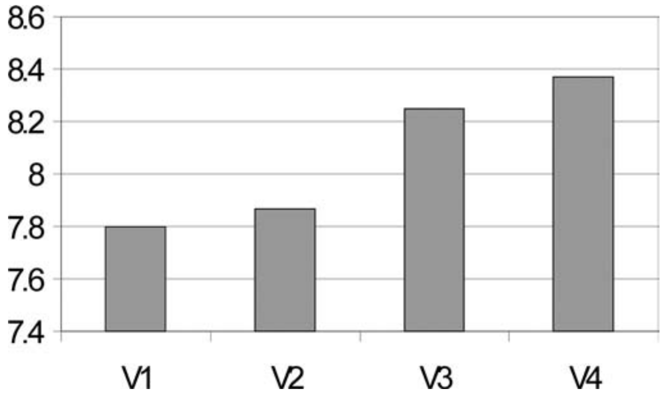

FIGURE 1 The number of tomato plant leaves.

RESULTS AND DISCUSSION

The results of the measurements for the number of tomato plant leaves, for the height of the tomato plants (cm), for the number of flowers and the absorbance versus wavelength for the three chemical compounds (V1 – control, V2 – $Mg(NO_3)_2$; V3 – $Ca(NO_3)_2$; V4 – $Ba(NO_3)_2$ are presented in the Figures 1–4.

For tomato plants stored in Biophysics Department number of tomato plant leaves, for the height of the tomato plants (cm) and the absorbance versus wavelength are presented in Figures 5–7.

Here O1 – control, O2 – $Mg(NO_3)_2$; O3 – $Ca(NO_3)_2$; O4 – $Ba(NO_3)_2$.

By treating the tomato plants with nitrates of group II-a bivalent metals, Mg, Ca, Ba, different effects were observed; these differences are the following:

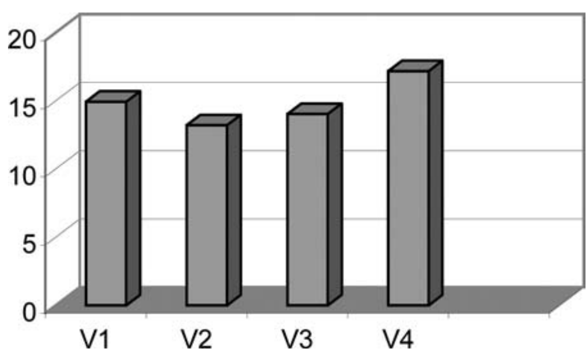

FIGURE 2 The height of the tomato plants.

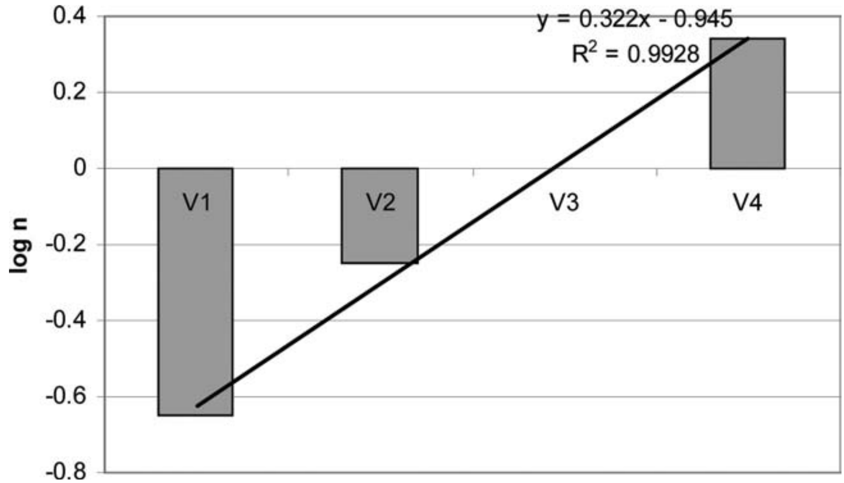

FIGURE 3 The number of the flowers of the tomato plants.

1. The average number of leaves and the height of the tomato plants treated with Ba are greater than that of the control plants.
2. The number of flowers of the plants treated with Ba is far greater than that the control (exponential) ones or of the ones treated with Mg and Ca.
3. The content of the photosynthetic pigments is greater in the case of the treated plants in comparison with the control. The content of pigments

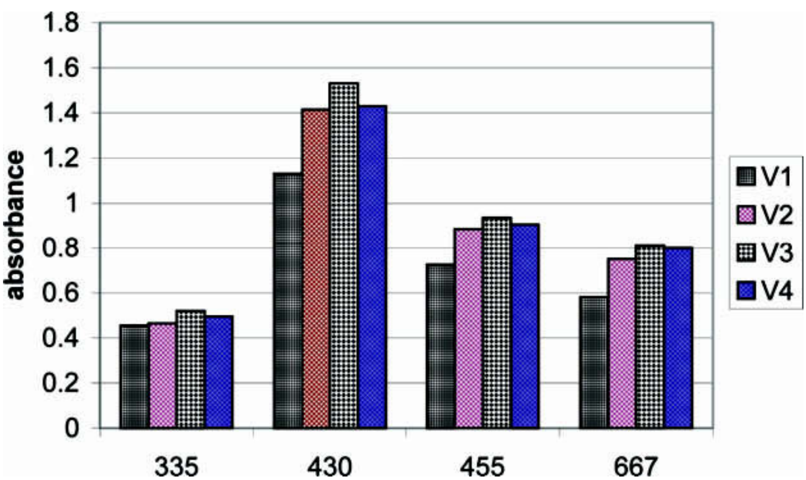

FIGURE 4 Absorbance versus wavelength for the three chemical compounds.

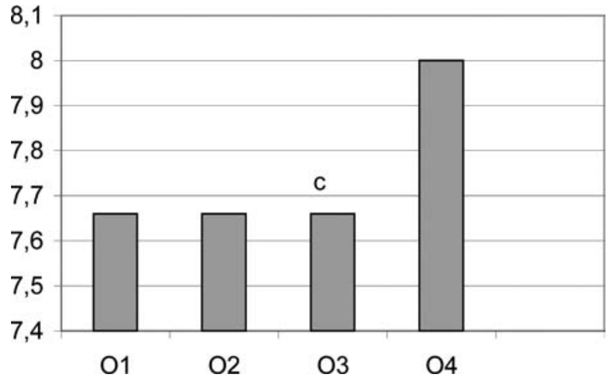

FIGURE 5 The number of tomato plant leaves.

however is a little bit different for the three cations. In the case of the plants that were grown in the Biophysics laboratory the content of pigments is smaller in the leaves of the plants treated with Ba in comparison with the ones treated with Mg and Ca. The biggest growth in the content of the pigments is observed in the case of the carothenoids.

Taking into account the fact that in all the cases the anion was the same, NO_3^-, it is obvious that the development of the plants is influenced by the metallic cation. This aspect must be related to the fact that these cations in solution form aquacomplex like $[Mg(H_2O)_6]^{2+}$, $[Ca(H_2O)_6]^{2+}$, $[Ba(H_2O)_6]^{2+}$, whose stability varies in this order:

$$[Mg(H_2O)_6]^{2+} > [Ca(H_2O)_6]^{2+} > [Ba(H_2O)_6]^{2+}.$$

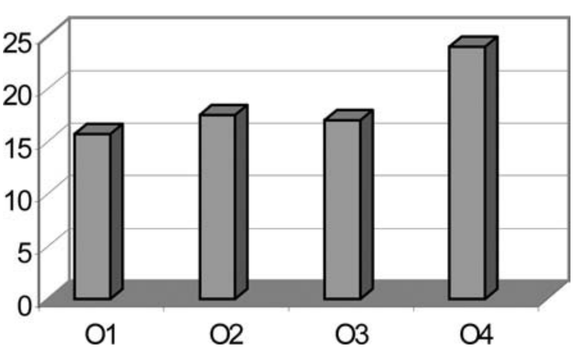

FIGURE 6 The height of the tomato plants.

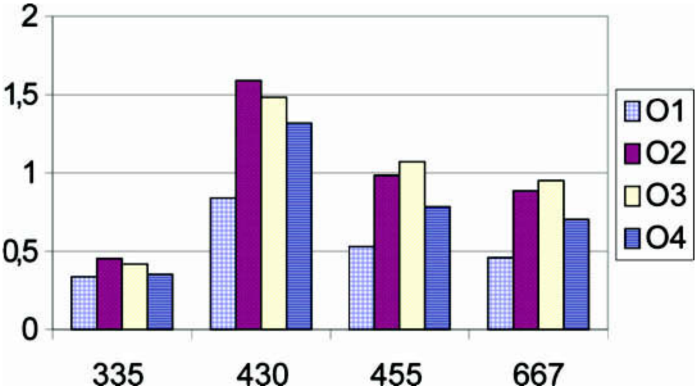

FIGURE 7 Absorbance versus wavelength.

Despite the considerable progress that has been made in the study of ions in aqueous solution, the origin of many ion-specific effects is still unknown.

The authors in [1] consider charge density of ions as a central determinant of the structure and function of biological systems. They suggest that most properties of biological systems arise from the fact that small ions of high charge density (kosmotropes) bind water molecules strongly, whereas large ions of low charge density (chaotropes) bind water weakly relative to the strength of water-water interaction in bulk solution.

A solution consisting of ions of various sizes will tend to segregate according to size. Oppositely charged ion of similar charge density tend to form inner sphere ion pair. When chaotrope form inner sphere ion pairs with chaotrope and kosmotrope with cosmotrope, they form the least soluble salts.

The nitrate's solubility of Mg^{2+}, Ca^{2+} and Ba^{2+}in water at 20°C is presented in Table 1.

The major intracellular anions, phosphates and carboxylates are kosmotropes, whereas the major intracellular monovalent cations are chaotropes. Together they form highly soluble, solvent – separated ion pairs that keep the contents of the cell in solution. The standard heat of solution is shown to be negative(exotermic) only when one ion is kosmotrope and the ion of opposite charge is a chaotrope.

Individual ions may be systematically classified as chaotropes or kosmotropes by the sign of the Jones – Dole viscosity B coefficient (negative or positive), respectively. The viscosity B coefficient correlates with charge density and it is defined by the expression:

$$\eta/\eta_0 = 1 + Ac^{1/2} + Bc,$$

TABLE 1

Nr.	Chemical compound	Solubility (g/100 g H_2O)
1	$Mg(NO_3)_2 * 6H_2O$	70.1
2	$Ca(NO_3)_2 * 4H_2O$	129.4
3	$Ba(NO_3)_2$	9.1

which is valid at the concentration c up to about 0.1 M for binary strong electrolytes. Here η is the viscosity of an aqueous salt solution η_0 is the viscosity of water at the same temperature and A is an electrostatic term that can be neglected at moderate concentration. The viscosity B coefficient is a measure of ion-water interactions.

The effects of the cations of the second group Mg^{2+}, Ca^{2+} , Ba^{2+} may be found on properties from the Table 2.

From this table it is observed that the ionic radius of the metallic cation grows in this group $Mg > Ca > Ba$. It is known that cations are hydratated more easily if the charge is greater and the ionic radius is smaller. The enthalpy is a measure of ion's attraction for water.

The surface charge density of Mg^{2+} is greater than that the other. At high surface densities, ion-water interactions become partially covalent, there is a substantial charge transfer to the solvent and the bound water molecules are partially ionized (the net charge on the central Mg^{2+} of $[Mg(H_2O)_6]^{2+}$ has been calculated to be only 1.18). Ca^{2+}, with a charge density apparently well matched to the phosphate, forms only sparingly soluble salts with phosphate whereas the smaller Mg^{2+} with its excess charge density forms moderately soluble salts with phosphate and typically remains partially hydrated. Mg^{2+}in biological systems interacts with cellular components via both inner and outer sphere complexes whereas Ca^{2+} apparently favors inner sphere complexes. Ca^{2+} also readily forms

TABLE 2

Property	Mg	Ca	Ba
Atomic radius(pm)	160	197	224
Ionic radius r(pm)	72	100	135
Surface area of spherical ion (in pm^2) $O = 4\pi r^2$	65111	125600	228906
Surface charge density $q/O * 10^5$	3.07	1.59	0.873
Intracellular concentration	40 mM	10^{-7}M	–
Extracellular concentration	1 mM	2.5 mM	–
Hidration enthalpy(KJ/mol)	1920	1650	1360
Jones-Dole viscosity B coefficients	0.385	0.285	0.22

insoluble carboxylate salts and Ca^{2+} binding sites on protein typically involve carboxylate groups.

Because of this, the stability of the Ba aquacomplex is the lowest. We would like to mention that in the case of other series of complexes the stability constants have the lowest values for the Ba^{2+} cation.

This means that this cation has the greatest impact in what faster development of the plants is concerned. Because the enzymes have a great impact in the development of the plants we suggest that the fast development of the plants treated with Ba^{2+} is due to the fact that the complex that contains Ba^{2+} transports the greatest quantity of water and enzymes.

An interesting influence of barium on biological systems is presented in [5]. The authors showed that channel – blocking compounds could alter or interfere with the opening and closing conformational changes of ion channels. They presented the influence of external Ba^{2+} on the gating charge movement of *Shaker* K^+ channels.

The cation Ba^{2+} blocks many classes of K^+ channels and has been widely to probe the structure of K^+ selective pores. External Ba^{2+} slightly decreases the quantity of ON gating charge upon depolarization to potential near –30 mV but has little effect on the quantity of charge upon stepping to more hyperpolarized or depolarized potentials. The actions of Ba^{2+} on the gating current are dose-dependent and are not produced by either Ca^{2+} or Mg^{2+}.

The authors suggest that Ba^{2+} binds to a specific site on the Shaker K^+ channel that destabilizes conformation and thus facilitates the return of gating charge upon repolarization. That means that the external Ba^{2+} can significantly speed the return of gating charge to its resting state.

CONCLUSIONS

We report the effect of each cation on number of plant leaves, height of plants, number of flowers and on photosynthetic pigments content. We have been performing these studies for 3 years and we are interested in development of plants and not in the final yield of tomatoes; that is why we stopped at that stage and because the studies were performed indoors (Biophysics Department Laboratory) the tomato plants could not reach maturity (until now we have focused on the effect of cations on the development of tomato plants until the stage of blooming). In the case of Ba^{2+} treatment the flowers proved to be strong enough to provide a good yield.

In our country we are interested not only on volume or weight of tomatoes but also on time of growth. The earlier plants are expensive on the markets and thus they have more economic efficiency for cultivators who grow tomato plants in order to sell them. The fast development of the plants treated with Ba^{2+} and the fact that many more flowers appeared in the case of Ba^{2+} treatment is also very important in the domain of floriculture, from point of view of economic efficiency; flower cultivators are very interested in obtaining earlier flowers and in large quantities to obtain substantial income.

The studies on the effects of cations on the yield of tomato plants will be continued next year when the tomato plants will be planted on a special soil in open air so we can measure the tomatoes weight.

We concluded that barium 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.

Though the Ba^{2+} cation is toxic to man, in this phase of the research the transmission of this cation to the leaves and the fruit of the plants was not measured. In the future we wish to make experiments that will show the limit dose that can be used without the plants being toxic to animal organism or to the soil.

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