Examination of Zn deficiency on some physiological parameters in case of maize and cucumber seedlings

Nóra Bákonyi
University of Debrecen, Institute of Plant Science, Division of Agricultural Botany and Crop Physiology,
Böszörményi u. 138. H-4032 Debrecen
E-mail: nbakonyi@agr.unideb.hu

SUMMARY

Zinc (Zn) is an essential micronutrient needed not only for people, but also crops. Almost half of the world's cereal crops are deficient in Zn, leading to poor crop yields. In fact, one-third (33%) of the world's population is at risk of Zn deficiency in rates, ranging from 4% to 73% depending on the given country. Zn deficiency in agricultural soils is also a major global problem affecting both crop yield and quality. The Zn contents of soils in Hungary are medium or rather small. Generally, the rate of Zn deficiency is higher on sand, sandy loam or soil types of large organic matter contents. High pH and calcium carbonate contents are the main reasons for the low availability of Zn for plants (Karimian and Moafpouryan, 1999). It has been reported that the high-concentration application of phosphate fertilisers reduces Zn availability (Khosgoftarmanesh et al., 2006). Areas with Zn deficiency are particularly extensive in Békés, Fejér and Tolna County in Hungary, yet these areas feature topsoils of high organic matter contents. Usually, Zn is absorbed strongly in the upper part the soil, and it has been observed that the uptakeable Zn contents of soil are lower than 1.4 mg kg^{-1}.

Maize is one of the most important crops in Hungary, grown in the largest areas, and belongs to the most sensitive cultures to Zn deficiency. Zn deficiency can causes serious damage in yield (as large as 80 %), especially in case of maize. On the other hand, Zn deficiency can also cause serious reduction in the yields of dicots. One of the most important vegetables of canning industry is cucumber, which is grown all over the world.

In this study, the effects of Zn deficiency have investigated on the growth of shoots and roots, relative and absolute chlorophyll contents, fresh and dry matter accumulation, total root and shoot lengths, the leaf number and leaf area of test plants in laboratory. Experimental plants used have been maize (Zea mays L. cv. Reseda sc.) and cucumber (Cucumis sativus L. cv. Delicatess). A monocot and dicot plant have chosen a to investigate the effects of Zn deficiency, because they have different nutrient uptake mechanism.

It has been observed that the unfavourable effects of Zn deficiency have caused damage in some physiological parameters, and significantly reduced the growth, chlorophyll contents of monocots and dicots alike.

***KEYWORDS*:** Zn deficiency, maize, cucumber, monocots, dicots

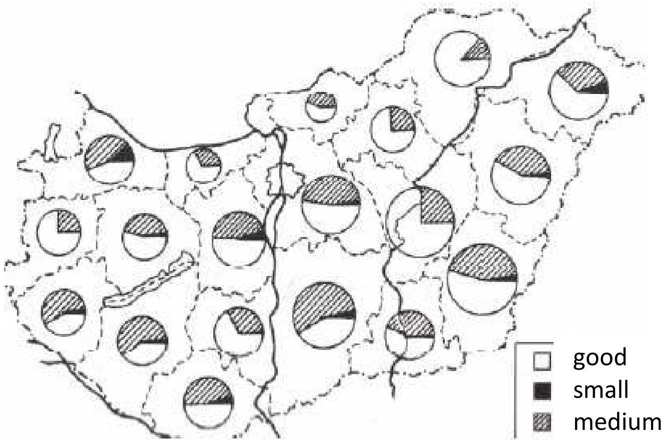
INTRODUCTION

The World Health Organization's "World Health Report 2002" estimated that one-third (33%) of the world's population is at risk of inadequate zinc intakes, ranging from 4% to 73% depending on the given country (WHO, 2002). The effects of zinc deficiency may be serious for human body, range from impaired neuropsychological functions, growth retardation and stunting, impaired reproduction, immune disorders, dermatitis, impaired wound healing, loss of appetite and hair. Zn is an essential micronutrient needed not only for people, but also crops. There are a number of physiological impairments in Zn-deficient plant cells with causing retardation of the growth, differentiation and development of plants (Cakmak, 2000), because the Zn is indispensable micronutrient for the plant via important enzyme-constituent and influence enzyme-activator. The Zn takes part in protein metabolism and stimulates the auxin production in due to regulate the growth (Pethő, 1993; Kalocsai, 2006).

Zn deficiency in soils is also a serious global problem affecting both crop yield and quality. Severe soil zinc deficiency can cause complete crop failure while losses of up to 30% can occur in yield of cereal grains in crops such as wheat, rice and maize as a result of even mild deficiencies. Maize is one the most important crops in Hungary, grown in the largest areas, and belongs to the most sensitive cultures to Zn deficiency. Zn deficiency can causes serious damage in yield (as large as 80 %), especially in case of maize. On the other hand, Zn deficiency can also cause serious reduction in the yields of dicots. One of the most important vegetables of canning industry is cucumber, which is grown all over the world. There are some differences between the monocots and dicots nutrient uptake mechanism. The plants of Strategy I. release by their roots protons and electrons, and make the rhizosphere pH lower. The plants belonging to the Strategy I group are the dicots. The mechanisms will be activated under iron deficiency. The grasses belong to the second - Strategy II- group (Marschner et al., 1986). Phytosiderophores (PS) are released in graminaceous species (Gramineae) under iron (Fe) and zinc (Zn) deficiency stress and PS have huge ecological significance for acquisition of Fe and presumably also of Zn (Römheld, 1991). The Zn contents of soils in Hungary are medium or rather small (*Figure 1*).

Generally, the rate of Zn deficiency is high on sand, sandy loam or soil types of large organic matter contents. High pH and calcium carbonate contents are the main reasons for the low availability of Zn for plants (Karimian and Moafpouryan, 1999). It has been reported that the high-concentration application of phosphate fertilisers reduces Zn availability (Khosgoftarmanesh et al., 2006; Kremper et al., 2009). Areas with Zn deficiency are particularly extensive in Békés, Fejér and Tolna County in Hungary, these areas feature topsoils of high organic matter contents. Usually, Zn is absorbed strongly in the upper part of the soil, and it has been observed that the uptakeable Zn contents of soil are lower than 1.4 mg kg^{-1}.

Figure *1*: **Zn contants of soils of Hungary**.



Remark: Kalocsai et al., 2006.

According to other scientist the critical deficiency level of Zn in the soil has been reported to be 0.6 mg kg^{-1} to 2.0 mg kg^{-1} that depends on the extraction method (Bhupinder et al., 2005). The critical Zn deficiency level was determined at 1.5 mg kg^{-1} by MÉM NAK in Hungary in case of using KCl-EDTA extractant (MÉM NAK, 1979).

MATERIAL AND METHODS

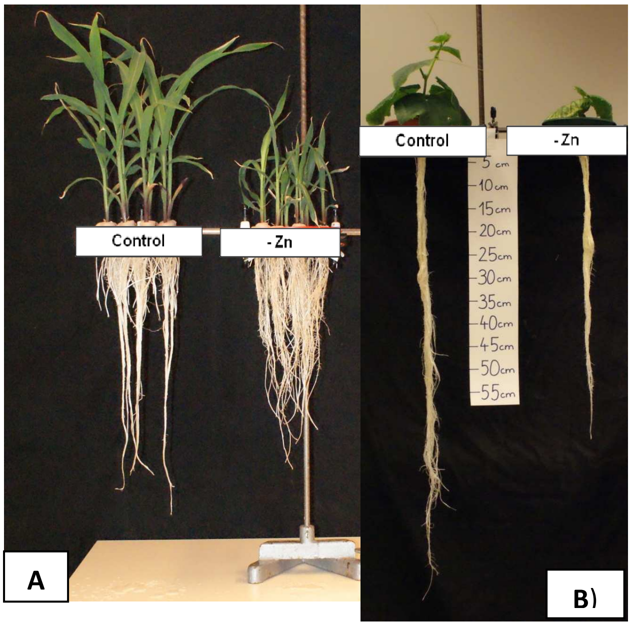
The experimental plants were corn (*Zea mays L. cvs. Reseda SC.*) and cucumber (*Cucumis stativum L. cv. Delicatess*). Monocot and dicot plants were chosen to investigate the effects of Zn deficiency, because they have different nutrient uptake mechanism.
The seeds were germinated on moistened filter paper at 25°C. The seedlings were transferred to a continuously aerated nutrient solution of the following composition: 2.0 mM $Ca(NO_3)_2$, 0.7 mM K_2SO_4, 0,5 mM $MgSO_4$, 0.1 mM KH_2PO_4, 0.1 mM KCl, 1µM H_3BO_3, 1µM $MnSO_4$, 0.25 µM $CuSO_4$, 0.01 µM $(NH_4)_6Mo_7O_{24}$. The nutrient solution of cucumber contains 10µM H_3BO_3. The iron as Fe-EDTA was added to the nutrient solution in a concentration of 10^{-4}M. The treatments were: control, -Zn (totally Zn deficiency), -Zn+NES. The auxin was used in synthetic form (NES) with 1 drop NES (0, 03369g=5,37x10^{-1}M) to the top of the stem on every 3th day.

In this study, the effects of Zn deficiency was investigated on the growth of shoots and roots, relative and absolute chlorophyll contents, fresh and dry matter accumulation, total root and shoot lengths, leaf number and leaf area of test plants in laboratory. The seedlings were grown under controlled environmental conditions (light/dark regime 10/14 h at 24/20 °C, 65–70% relative humidity and a photosynthetic photon flux density 300 µmol $m^{-2}s^{-1}$. The relative chlorophyll contents were measured with SPAD 502 (Minolta) on the 6th and 14th day in the case of maize and on the 16th and 22th day in the case of cucumber, on the 2nd leaf, respectively. The dry matter contents were measured with OHAUS Explorer appliance.

RESULTS AND DISCUSSION

Zn deficiency in agricultural production is a major global problem. Zn deficiency can causes serious damage in yield, especially in the case of maize.
As our results show, that the unfavourable effects of Zn deficiency have caused damage in growth of shoots and roots of monocots and dicots alike (*Picture 1*).

Picture *1*: **The effects of Zn deficiency on 14-day old maize (A) and 23-day old cucumber (B) seedlings.**



Remark: Bákonyi, N. 2010.

The nutrient solution without Zn significantly retarded the growth of shoots and roots in case of 14-day old maize and 23-day old cucumber as well. The results of the dry matter accumulations were shown in the *Table 1*.

Table 1.

The effect of different treatments on the dry matter accumulation of maize and cucumber seedlings (g plant-1). Significant difference comparison to the control: *p <0.05, **p<0.01, ***p<0.001.

Treatments	maize		cucumber	
	shoot	root	shoot	root
Control	0,61±0,16	0,17±0,06	3,55±0,56	0,86±0,11
- Zn	0,34±0,10***	0,13±0,04*	2,46±0,06*	0,32±0,10***
- Zn+NES	0,32±0,06***	0,13±0,03*	2,50±0,36*	0,61±0,13*

Remark: Bákonyi, N. 2010.

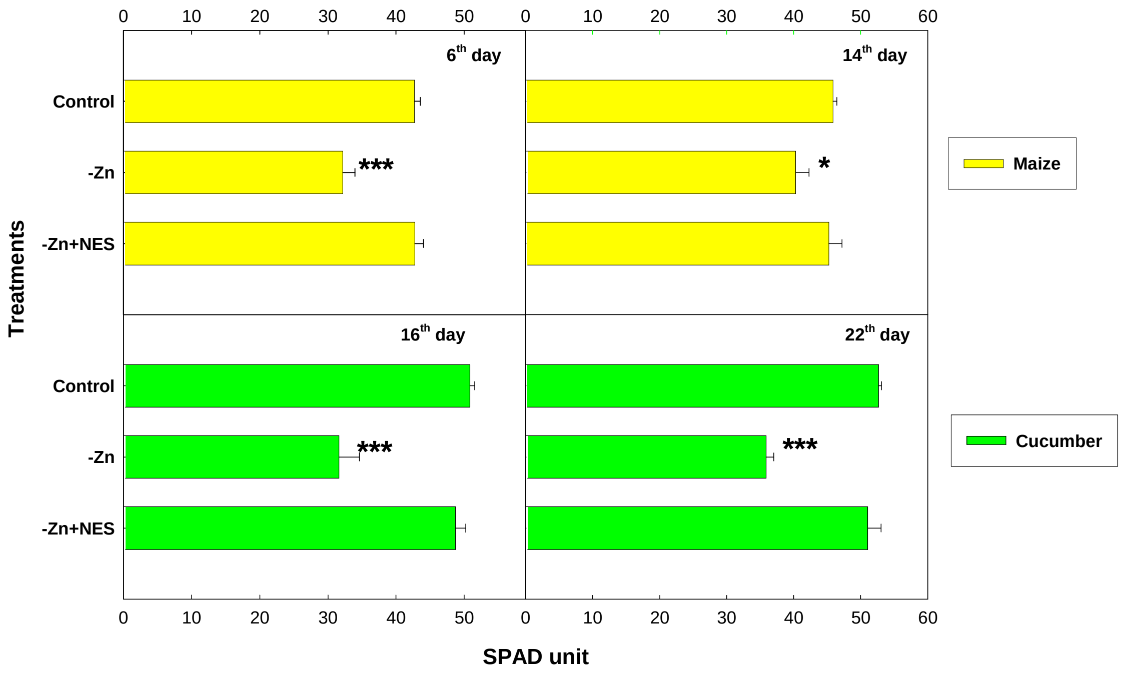
The –Zn treatment significantly reduced the dry matter accumulation, especially in case of shoots of maize with 44.4% and roots of cucumber with 63.1%. When NES was added to the Zn deficient cucumber plant the dry matter production of roots was higher with 91.7% from the –Zn treatment. The NES influenced the growth of roots and in contempt of Zn deficiency; the Zn is indispensable micronutrient for the plant via important enzyme-constituent and influence enzyme-activator. The Zn takes part in protein metabolism and stimulate the auxin production in due to regulate the growth (Pethő, 1993; Kalocsai, 2006).

The dry matter production depends on the intensity of photosynthesis and also on the contents of photosynthetic pigments. The relative chlorophyll contents (SPAD unit) were also measured on the 2nd leaves of experimental plants (*Figure 2*).

In the case of Zn deficiency the relative chlorophyll contents of maize and cucumber dramatically decreased in both measuring day. In the case of maize the relative chlorophyll contents of Zn-deficient plants were decreased with 24.7% on the 6th day and with 12.4% on the 14th day comparison to the control. The treatment with NES could compensate the effect of Zn deficiency and therefore the relative chlorophyll contents were similar to the control (on the 6th measuring day control: 42.70±3.62, -Zn+NES: 42.73±4.33; on the 14th measuring day control: 45.87±2.39; -Zn+NES: 45.87±7.15).

In cucumber the relative chlorophyll contents of Zn-deficient plants were lower, than the control with 37.7% on the 16th measuring day and with 31.8% on the 22th measuring day. When the –Zn treatment was completed with NES the relative chlorophyll contents of cucumber were 35% higher than in the totally Zn deficient plants on the 16th measuring day and with 29.5% on the 22th measuring day.

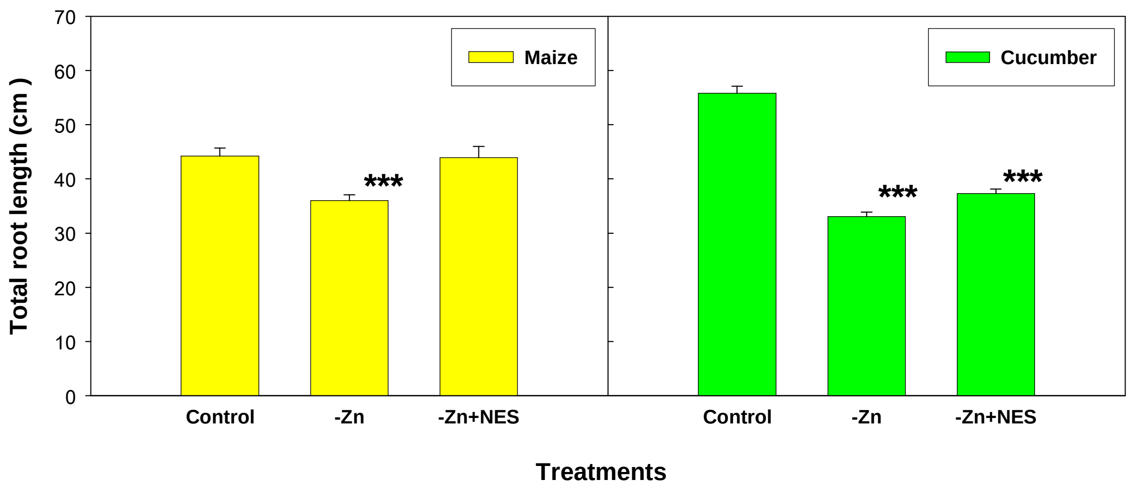
Figure *2*. **The effect of different treatments on the relative chlorophyll contents of maize and cucumber seedlings. (SPAD unit). (maize: n=475 cucumber: n=250). Significant difference comparison to the control: *p <0.05, **p<0.01, ***p<0.001.**



Remark: Bákonyi, N. 2010.

The effect of Zn deficiency and NES was measured on the total root length of maize and cucumber seedlings (*Figure 3*).

Figure *3*. **The effect of Zn deficiency and NES on the total root length of 14-day old maize and 23-day old cucumber seedlings. Significant difference comparison to the control: *p <0.05, **p<0.01, ***p<0.001.**



Remark: Bákonyi, N. 2010.

According to our experimental results one of unfavourable effects of Zn deficiency was decreased the total root length with 43.9% (maize) and 39.9% (cucumber). The total root length of Zn deficient test plants was significantly shorter, than the control; although the NES treatment could compensate the root length reduce effect of Zn deficiency in case of maize (control:44.17±7.96, -Zn:25.99±5.41, -Zn+NES:43.94±8,91), but not significant (with 11.1%) in case of cucumber.

It has been observed that the unfavourable effects of Zn deficiency have caused damage in some physiological parameters in consequence significantly reduced the growth of shoots and roots of monocots and dicots alike, the nutrient solution without Zn significantly retarded the growth of shoots and roots in case of 14-day old maize and 23-day old cucumber as well.

According to our results the unfavourable effects of Zn deficiency have caused damage in dry matter production. The –Zn treatment significantly reduced the dry matter accumulation, especially in case of shoots of maize with 44.4% and roots of cucumber with 63.1 %. When NES was added to the Zn deficient cucumber plant the dry matter production of roots was higher with 91.7% from the –Zn treatment.

In the case of maize the relative chlorophyll contents of Zn-deficient plants were decreased with 24.7% on the 6^{th} day and with 12.4% on the 14^{th} day comparison to the control. The treatment with NES could compensate the effect of Zn deficiency and therefore the relative chlorophyll contents were similar to the control. In case of cucumber the relative chlorophyll contents of Zn-deficient plants were lower, than the control with 37.7% on the 16^{th} measuring day and with 31.8% on the 22^{th} measuring day. When the –Zn treatment was completed with NES the relative chlorophyll contents of cucumber with 35 % were higher than the totally Zn deficient plants on the 16^{th} measuring day and with 29.5% on the 22^{th} measuring day.

The total root length was also dramatically retarded by Zn deficiency length with 43.9% (maize) and 39.9% (cucumber) although the NES treatment could compensate the root length reduce effect of Zn deficiency.

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