ACTA Acta Sci. Pol., Hortorum Cultus 8(2) 2009, 37-43

EFFECT OF CHELATED AND MINERAL FORMS OF MICRONUTRIENTS ON THEIR CONTENT IN LEAVES AND THE YIELD OF LETTUCE. PART III. ZINC

Elżbieta Kozik, Wojciech Tyksiński, Andrzej Komosa
University of Life Sciences in Poznań

Abstract. In 2-year seasonal experiments (cultivation in peat), the effect of chelated and mineral forms of zinc on the yield of greenhouse lettuce and on the content of zinc, copper, manganese and iron in lettuce leaves were compared. The following zinc doses were applied: 10, 20, 30, and 60 mg dm^{-3} of substrate. Using both forms of zinc in the studied range, good and similar yields were obtained. Zinc application in the mineral form caused a twice greater zinc concentration in lettuce leaves and a higher concentration of manganese, while copper and iron showed smaller concentrations.

Key words: lettuce, zinc chelate and zinc sulphate, content of micronutrients

INTRODUCTION

Deficit as well as excess of microelements are not favourable both for human beings and for plants. Zinc deficit is frequently encountered in the soils of all continents [Ruszkowska and Wojcieska-Wyskupajtys 1996]. This shortage limits the world production of food, particularly of cereals, rice and maize. Next to a favourable effect on living organisms including plants, microelements may cause a number of toxic effects when they occur in excessive concentrations in nutrient medium. Plant tolerance to excessive concentration of zinc is very differentiated [Łyszcz and Ruszkowska 1991, Roszyk et al. 1988]. The degree of plant tolerance in relation to zinc depends primarily on the form in which it occurs in soils and substrates, besides, it depends on zinc solubility and on the factors on which this ability depends, like soil reaction, granulometric composition, redos potential, content of organic substances, as well as on one of the basic cations (among others on Ca and Mg) [Spiak et al. 2000].

Corresponding author – Adres do korespondencji: Elżbieta Kozik, Wojciech Tyksiński, Andrzej Komosa, Department of Horticultural Plant Nutrition, University of Life Sciences in Poznań, ul. Zgorzelecka 4, 60-199 Poznań, Poland, e-mail: knaw@au.poznan.pl

There exist many publications referring to many crops fertilized with zinc. During the last two decades, the effects of zinc forms [Spiak 1996] and chelated zinc forms are compared [Spiak 1996, Hoffmann et al. 2004] regarding their effects on the yield, their quality and metal content in plants.

The objective of the presented studies was the comparison of the effect of zinc applied in the form of zinc sulphate and zinc chelate Zn – EDTA+DTPA on the yield of lettuce and its nutritional status with zinc.

MATERIAL AND METHODS

Pot experiments with head lettuce 'Michalina' cultivar were carried out in spring periods of the years 2006–2007 in an unheated greenhouse. Experimental factors included:

1. zinc form:

– zinc chelate Forte 14 Intermag Co. [Zn (II) DEDTA + Zn (II) DTPA],

– zinc sulphate [Zn $SO_4 \cdot 7H_2O$],

2. zinc level – 4 levels: 10, 20, 30 and 60 mg dm^{-3}.

Lettuce seedlings in the phase of two proper leaves were planted on the 13th of April into 6 dm^3 containers filled with substrate prepared of highmoor peat. The substrate was limed on the basis of neutralization curve to pH in H_2O = 6.3 and it was enriched with nutritive components in the form of salt solutions. After liming, the contents of Ca – 2045, Mg – 160, S-SO_4 – 25 mg dm^{-3} were found to be sufficient, therefore, they were not supplemented. The remaining macro- and microcomponents in the substrate were supplemented to the following levels (mg dm^{-3}): N – 180, P – 140, K – 220, Fe – 50, Mn – 20, Cu – 5, B – 1, Mo – 1.

Zinc was applied according to the assumption of the experiment after the consideration of the initial content, which after peat liming amounted to 2 mg dm^{-3}. Each combination included 4 containers as replication with 4 plants in each container.

A detailed description of experimental conditions, chemical analyses and statistical estimations were presented in part I. of this work [Kozik et al. 2008a].

RESULTS AND DISCUSSION

Lettuce yield is shown in table 1. No differences in the yields of lettuce fertilized with the chelated and the sulphatic forms of zinc were found. Also, no differences were found in the yielding caused by the differentiated zinc doses. The highest applied dose was 60 mg Zn dm^{-3} of substrate. Tyksiński [1984], after the application of the dose of 60 mg Zn dm^{-3} (zinc sulphate) in lettuce grown in peat, also obtained yields not differing from those obtained with lower Zn doses (i.e. with 5 and 20 mg Zn dm^{-3}). In the quoted work, only the Zn dose of 180 mg dm^{-3} caused a significant reduction of lettuce yield. In this study a significant difference was found in the yields between the particular years. Lettuce yield, independent of the zinc form and its dose, was higher in the year 2007.

Table 1. Lettuce yield (g container^{-1}), depending on the form and the level of zinc in the substrate
Tabela 1. Plon sałaty (g·pojemnik^{-1}) w zależności od postaci i poziomu cynku w podłożu

Zn level Poziom Zn mg dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of zinc postać cynku		mean średnia	form of zinc postać cynku		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
10	513.5	497.0	505.2	563,5	543,0	553,2	529,2
20	508.7	491.2	500.0	554,7	611,7	583,2	541,6
30	462.0	493.0	477.5	522,7	567,0	544,9	511,2
60	477.5	478.0	477.7	569,0	554,2	561,6	519,7
Mean – Średnia	490.4	489.8		552,5	569,0		
Mean for years Średnia dla lat	490.1			560.8			
Mean for form Średnia dla postaci	Chelate – Chelat – 521.5			Sulphate – Siarczan – 529.4			

Factors – Czynniki: A – forms – postaci, B – levels – poziomy, C – years – lata.
n.s. – not significant – r.n. – różnice nieistotne.
$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
A – n.s. – r.n., B – n.s. – r.n., C – 43.87, A×C – n.s. – r.n., B×C n.s. – r.n., A×B×C – n.s. – r.n.

Zinc content in lettuce leaves is shown in table 2. The sulphatic form of zinc caused almost a twice greater zinc content than the chelated form. Spiak [1996] studied the effect of different zinc forms (including $ZnSO_4$ and Zn – EDTA) on the yield of oat and mustard and on zinc content in these plants. After the application of $ZnSO_4$, the mentioned author obtained smaller plant yields and a smaller zinc content in plants than after the application of Zn – EDTA. An inverse dependence in relation to the discussed work could have resulted from the application of another chelate, i.e. Zn – EDTA+DTPA. Studies of microelement chelation in this zinc using EDTA, DTPA, HEEDTA and citric acid were carried out by Hoffmann et al. [2004]. The best results in zinc chelation were obtained by the authors when they applied citric acid.

Independent of the form of the applied zinc, its content in plants increased with the zinc dose in the substrate. Increase of zinc dose from 10 to 60 mg dm^{-3} in the form of zinc sulphate caused an increase of zinc content in lettuce leaves from 141.7 to 299.4 mg Zn kg^{-1} (mean value from two years). In the work of Tyksiński [1986], the increase of zinc dose from 5 to 60 mg dm^{-3} in the same form caused zinc content increase from 133 to 333 mg Zn kg^{-1}. Results from the above mentioned studies are very similar. The Zn concentration of 333 mg kg^{-1} exceeded the zinc content range in lettuce 84–288 mg kg^{-1} [Tyksiński 1992], determined for the zinc dose range 0–40 mg Zn dm^{-1} in which the obtained lettuce yields did not differ and they were free of any symptoms of zinc deficit or excess.

Differentiated zinc fertilization exerted an influence on the nutritional status of lettuce with copper, manganese and iron. Zinc doses in the chelated and the sulphatic forms exerted a significant effect on copper content (tab. 3). Lettuce fertilized with the chelated zinc form contained more copper than in case of the fertilization with the sulphatic zinc form. In both years of studies, lettuce fertilized with zinc in the doses of

20–60 mg dm^{-3} contained more copper than fertilized with the dose of 10 mg dm^{-3}. It was also found that the lettuce contained more copper in 2007 than in the year 2006.

Table 2. Zinc content (mg kg^{-1} d.m.) in lettuce, depending on the form and level of zinc in the substrate
Tabela 2. Zawartość cynku (mg·kg^{-1}s.m.) w sałacie, w zależności od postaci i poziomu cynku w podłożu

Zn level Poziom Zn mg dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of zinc postać cynku		mean średnia	form of zinc postać cynku		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
10	62.7	128.6	95.6	89.4	154.7	122.1	108.9
20	80.1	189.1	134.6	110.9	204.6	157.8	146.2
30	102.8	214.2	158.5	138.7	223.7	181.2	169.9
60	141.8	291.1	216.5	168.2	307.7	237.9	227.2
Mean – Średnia	96.9	205.8		126.8	222.7		
Mean for years Średnia dla lat	151.4			174.8			
Mean for form Średnia dla postaci	Chelate – Chelat – 111.9			Sulphate – Siarczan – 214.3			

Factors – Czynniki: A – forms – postaci, B – levels – poziomy, C – years – lata.
n.s. – not significant – r.n. – różnice nieistotne.
$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
A – 7.01, B – 9.91, C – 7.01, A×C – n.s. – r.n., B×C – n.s. – r.n., A×B×C – n.s. – r.n.

Table 3. Copper content (mg kg^{-1} d.m.) in lettuce. depending on the form and level of zinc in the substrate
Tabela 3. Zawartość miedzi (mg·kg^{-1}s.m.) w sałacie. w zależności od formy i poziomu cynku w podłożu

Zn level Poziom Zn mg dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of zinc postać cynku		mean średnia	form of zinc postać cynku		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
10	12.3	8.4	10.4	13.2	10.6	11.9	11.2
20	13.2	10.4	11.8	13.9	11.2	12.5	12.2
30	14.1	8.4	11.2	14.6	10.2	12.4	11.8
60	15.1	7.7	11.4	17.0	10.6	13.8	12.6
Mean – Średnia	13.7	8.7		14.7	10.6		
Mean for years Średnia dla lat	11.2			12.7			
Mean for form Średnia dla postaci	Chelate – Chelat – 14.2			Sulphate – Siarczan – 9.7			

Factors – Czynniki: A – forms – postaci, B – levels – poziomy, C – years – lata.
n.s. – not significant – r.n. – różnice nieistotne.
$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
A – 0.46. B – 0.65. C – 0.46. A×C – n.s – r.n.. B×C – n.s. – r.n.. A×B×C –n.s. – r.n.

Manganese content in lettuce leaves is shown in table 4. After the application of the sulphatic form of zinc, the content of manganese was over twice higher than after the application of the chelated form, The applied zinc doses did not show any explicit effect on the manganese content. In an earlier work, Tyksiński [1993] found synergism between zinc and manganese. The content of manganese in both years of studies differed significantly and it was significantly higher in the year 2007.

Table 4. Manganese content (mg kg^{-1} d.m.) in lettuce. depending on the form and level of zinc in the substrate
Tabela 4. Zawartość manganu (mg·kg^{-1} s.m.) w sałacie. w zależności od formy i poziomu cynku w podłożu

Zn level Poziom Zn mg dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of zinc postać cynku		mean średnia	form of zinc postać cynku		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	Sulphate Siarczan		
10	165.0	273.7	219.4	216.9	401.9	309.5	264.4
20	140.3	307.9	224.1	189.7	435.6	312.6	268.4
30	146.2	288.2	217.2	170.0	408.4	289.2	253.2
60	149.9	328.0	238.9	190.3	404.4	297.3	268.1
Mean – Średnia	150.4	299.5		191.7	412.6		
Mean for years Średnia dla lat	224.9			302.2			
Mean for form Średnia dla postaci	Chelate – Chelat – 171.1			Sulphate – Siarczan – 356.1			

Factors – Czynniki: A – forms – postaci, B – levels – poziomy, C – years – lata.
$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
A – 6.61, B – 9.35, C – 6.61, A×C – 9.35, B×C – 13.22, A×B×C – 18.70

The content of iron in lettuce leaves is presented in table 5. A higher content of iron in lettuce was found after the application of the chelated form of zinc, in comparison with the sulphatic zinc form. The Zn dose of 20 mg dm^{-3} comparison with 10 mg caused a significant increase of iron content in lettuce leaves. On the other hand in relation to the zinc doses of 10 and 20 mg dm^{-3} a significant increase of iron content in lettuce leaves was found after the application of zinc in the amount of 60 mg dm^{-3} of substrate. In the year 2007, iron content in lettuce leaves was higher than in the previous year.

Similarly as in the earlier studies [Kozik et al. 2008a, 2008b] with chelated and mineral forms of manganese and copper, a greater content of iron was shown in plants where the chelated form of zinc was applied, in comparison with plants fertilized with the mineral zinc form. The contents of zinc and manganese obtained in lettuce in our studies generally exceeded the content ranges reported by Kabata-Pendias and Pendias [1999] as the most frequently encountered values in leafy vegetables. On the other hand, the contents of copper and iron were contained in those ranges.

Table 5. Iron content (mg kg^{-1} d.m.) in lettuce depending on the form and level of zinc in the substrate
Tabela 5. Zawartość żelaza (mg·kg^{-1} s.m.) w sałacie w zależności od postaci i poziomu cynku w podłożu

Zn level Poziom Zn mg dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of zinc postać cynku		mean średnia	form of zinc postać cynku		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
10	160.7	134.3	147.5	190.5	187.1	188.8	168.2
20	177.9	136.2	157.0	197.9	204.3	201.1	179.1
30	188.3	134.6	161.5	224.3	198.0	211.2	186.4
60	191.8	138.0	164.9	228.8	207.8	218.3	191.6
Mean – Średnia	179.7	135.8		210.4	199.3		
Mean for years Średnia dla lat	157.7			204.9			
Mean for form Średnia dla postaci	Chelate – Chelat – 195.1			Sulphate – Siarczan – 167.6			

Factors – Czynniki: A – forms – postaci, B – levels – poziomy, C – years – lata.
n.s. – not significant – r.n. – różnice nieistotne.
$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
A – 5.75, B – 8.13, C – 5.75, A×C – 8.13, B×C – n.s. – r.n., A×B×C – n.s. – r.n.

Summing up all three parts of the presented studies (Parts I–III – Kozik et al. 2008a, 2008b] one can conclude that lettuce grown in a substrate fertilized with zinc and magnesium in the mineral form contained more of these metals, than after the application of the chelated forms. An inverted dependence was found in relation to copper. It could be connected with more intensive linkage of copper by the peat substrate than zinc and manganese. Further studies are needed in order to finally explain the usefulness of the mineral and chelated forms of microelements for the fertilization of horticultural plants.

CONCLUSIONS

1. Effect of zinc sulphate and zinc chelate (Zn – EDTA + DTPA) on the yielding of lettuce was the same. Yields obtained in the range of Zn doses 10–60 mg dm^{-3} did not differ.
2. Zinc content in lettuce leaves, after the application of the mineral form was twice higher than after the application of the chelated form.
3. Lettuce fertilized with the chelated zinc form contained more copper and iron and less manganese than fertilized with the mineral form.

REFERENCES

Hoffmann J., Hoffmann K., Górecka H., 2004. Chelaty mikronawozowe w roztworach zawierających makroskładniki nawozowe. Zesz. Probl. Post. Nauk Roln. 502, 791–795.

Kabata-Pendias A., Pendias H., 1999. Biogeochemia pierwiastków śladowych. Wyd. Nauk. PWN, Warszawa.
Kozik E., Tyksiński W., Komosa A., 2008a. Effect of chelated and mineral forms of micronutrients on their content in leaves and the yield of lettuce. Part I. Manganese. Acta Sci. Pol., Hortorum Cultus, 7(1), 73–82.
Kozik E., Tyksiński W., Komosa A., 2008b. Effect of chelated and mineral forms of micronutrients on their content in leaves and the yield of lettuce. Part II. Copper. Acta Sci. Pol., Hortorum Cultus, 7(3), 25–31.
Łyszcz S., Ruszkowska M., 1991. Zróżnicowana reakcja kilku gatunków roślin na nadmiar cynku. Roczn. Glebozn. 42(3/4), 215–221.
Roszyk E., Roszyk S., Spiak Z., 1988. Toksyczna dla roślin zawartość cynku w glebach. Roczn. Glebozn. 39(3), 57–69.
Ruszkowska M., Wojcieska-Wyskupajtys U., 1996. Mikroelementy – fizjologiczne i ekologiczne aspekty ich niedoborów i nadmiarów. Zesz. Probl. Post. Nauk Roln. 434, 1–11.
Spiak Z., 1996. Wpływ formy chemicznej cynku na pobieranie tego pierwiastka przez rośliny. Zesz. Probl. Post. Nauk Roln. 434, 997–1003.
Spiak Z., Romanowska M., Radoła J., 2000. Toksyczna zawartość cynku w glebach dla różnych gatunków roślin uprawnych. Zesz. Prob. Post. Nauk Roln. 471, 1125–1142.
Tyksiński W., 1984. Reakcja sałaty szklarniowej uprawianej w torfie na zróżnicowane nawożenie mikroelementami. I. Plonowanie oraz objawy zewnętrzne niedoboru i nadmiaru mikroelementów. PTPN, Pr. Kom. Nauk Rol. Leś., 57, 299–308.
Tyksiński W., 1986. Reakcja sałaty szklarniowej uprawianej w torfie na zróżnicowane nawożenie mikroelementami. III. Zmiany zawartości mikroelementów w roślinach. PTPN, Pr. Kom. Nauk Rol. Leś. 61, 239–248.
Tyksiński W., 1992. Reakcja sałaty szklarniowej na zróżnicowane nawożenie mikroelementami. Roczn. AR w Poznaniu. Rozpr. Nauk. 233.
Tyksiński W., 1993. Reakcja sałaty szklarniowej uprawianej w torfie na zróżnicowane nawożenie mikroelementami. VI. Interakcje między mikroelementami. PTPN, Pr. Kom. Nauk Rol. Leś. 75, 155–160.

WPŁYW CHELATOWYCH I MINERALNYCH FORM MIKROSKŁADNIKÓW NA ICH ZAWARTOŚĆ W LIŚCIACH ORAZ NA PLON SAŁATY. CZĘŚĆ III. CYNK

Streszczenie. W 2-letnich doświadczeniach sezonowych (uprawa w torfie) porównywano wpływ chelatowej i mineralnej formy cynku na plon sałaty szklarniowej oraz zawartość w jej liściach cynku, miedzi, manganu i żelaza. Zastosowano dawki cynku: 10, 20, 30 i 60 mg·dm^{-3} podłoża. Stosując obie formy cynku, uzyskano w badanym zakresie dawkowania cynku dobre, nieróżniące się plony sałaty. Zastosowanie cynku w formie mineralnej spowodowało 2-krotnie większą koncentrację cynku w liściach sałaty, spowodowało także większą koncentrację manganu oraz mniejszą miedzi i żelaza.

Słowa kluczowe: sałata, chelat i siarczan cynku, zawartość mikroskładników

Accepted for print – Zaakceptowano do druku: 1.06.2009