ACTA Acta Sci. Pol., Hortorum Cultus 7(3) 2008, 25-31

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

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Abstract. In pot experiments, in spring 2006 and 2007, a comparison was made between the chelated and the mineral forms of copper on the yielding of lettuce and on the content of Cu, Zn, Mn and Fe in lettuce leaves. Plants were grown in peat substrate supplemented with Cu doses of 5, 25, 50 and 75 mg·dm^{-3}. A greater mass of lettuce heads was obtained after the application of the mineral form of copper. In the range of doses: 5–50 mg Cu·dm^{-3}, the mean yields of lettuce did not differ. In the second year of studies, the application of copper chelates in the dose of 75 mg·dm^{-3} caused a high reduction of yield. The mean copper content in lettuce, after the application of the chelated Cu form, was twice higher than after the use of the mineral Cu form. Iron content in lettuce after the application of copper chelates was higher than after the use of copper sulphate, while the contents of zinc and manganese were smaller.

Key words: lettuce, copper chelate and copper sulphate, yield, microcomponent

INTRODUCTION

Copper is a microelement which is indispensable for the correct growth and development of plants [Kabata-Pendias and Pendias 1999]. According to the same authors, the mean copper content in the aboveground plant parts amounts to 5–20 mg·kg^{-1}. Vegetables are the essential source of copper and of other microelements for humans. Numerous publications published during the past 20 years indicate a low content of copper in vegetables. Wachnik [1987] reported about increasing deficits of copper in food. The World Health Organization recommends that adults should consume 2–3 mg of copper daily. According to Ziemlański et al. [1994], the recommended and safe level of the daily dose of consumed copper should be 2.0–2.5 mg for adults above the age of 19

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years. On the other hand, the real daily consumption does not exceed 50% of the recommended dose [Tyksiński 1992]. The task of fertilization specialists is to improve the content of copper and other microelements in food, particularly in vegetables. Studies are carried out on the increase of copper content in the crops by the application of different copper compounds and different doses of this element [Spiak and Śmiatacz 2004]. There are also studies which compare the effects of chelated and mineral forms of copper and of other microelements on the nutritional status of plants.

The objective of this work was the comparison of the effect of the chelated and the mineral forms of copper on the yielding of lettuce and on the content of micronutrients in lettuce leaves.

MATERIAL AND METHODS

In the years 2006–2007, two experiments were carried out with head lettuce of `Michalina` cultivar. In both years of studies, the plants were grown in spring, in an unheated greenhouse. The experimental factors included:

1. copper form

– copper chelate Forte 12 from Intermag Co. [Cu(II)EDTA+Cu(II)DTPA]

– copper sulphate ($CuSO_4 \cdot 5H_2O$)

2. copper level – 4 levels: 5, 25, 50 and 75 mg $Cu \cdot dm^{-3}$

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 raised peat. The substrate was limed on the basis of neutralization curve to the value of pH in H_2O = 6.3 and it was enriched with nutritive components in the form of salt solution. After liming, it was found that the contents of Ca (2045 mg), Mg (160 mg) and $S\text{-}SO_4$ (25 mg)$\cdot dm^{-3}$ were sufficient and therefore, these components were not supplemented. The remaining macro- and microcomponents in the substrate were supplemented, giving the following final levels ($mg \cdot dm^{-3}$): N – 180, P – 140, K – 220, Fe – 50, Zn – 20, Mn – 20, B – 1, Mo – 1.

Copper was applied according to the assumptions accepted in the experiment taking into consideration its initial content which after liming amounted to 0.5 mg $Cu \cdot dm^{-3}$.

Each combination included 4 containers as replications, with 4 lettuce plants in each container.

Detailed description of the remaining experimental conditions, chemical analyses and statistical estimations have been given in the first part of this work [Kozik et al. 2008].

RESULTS AND DISCUSSION

The mean mass of lettuce heads depended on the form and on the dose of copper and on the year of studies (tab. 1). Significantly greater mass of heads was obtained after the application of copper sulphate than after the use of copper chelate. In the range of copper doses of 5–50 mg $Cu \cdot dm^{-3}$, the mean lettuce yield did not differ. After the application of the dose of 75 mg Cu·dm^{-3}, the mean yield significantly decreased which was mainly caused by the chelated form applied in the second year of studies. After this form application, the yield decreased almost by one half. In the first year of studies, after the application of 75 mg Cu·dm^{-3} in the chelated form, the yield did not differ from the yield obtained after the use of the remaining copper doses. Tyksiński [1984], in his lettuce grown in peat, obtained yield which did not differ in the range of doses from 25 to 90 mg·dm^{-3} in the form of $CuSO_4$ anhydride. Chohura et al. [2004] compared the effectiveness of the chelated and mineral forms of copper and he did not find any positive effect of copper chelate on the yielding of tomato. The yield of lettuce obtained in the year 2007 (independent of Cu form) was significantly higher than that in 2006.

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

Cu level Poziom Cu mg·dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of copper postać miedzi		mean średnia	form of copper postać miedzi		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
5	485.7	492.0	488.9	518.5	611.7	565.1	527.0
25	492.0	487.5	489.7	565.5	589.7	577.6	533.7
50	536.5	496.0	516.2	506.5	576.0	541.2	528.7
75	496.5	498.7	497.6	320.5	598.2	459.4	478.5
Mean – Średnia	502.7	493.6		477.7	593.9		
Mean for years Średnia dla lat	498.1			535.8			
Mean for form Średnia dla postaci	Chelate – Chelat – 490.1			Sulphate – Siarczan – 543.7			

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 – 20.21, B – 28.58, C – 20.21, A×C – 28.58, B×C – 40.42, A×B×C – 57.16

The analysis of copper content in lettuce, depending on the form and dose of copper (tab. 2), showed that it was twice bigger after the application of the chelated form. Under the influence of increasing copper doses (independent of Cu form), its content in lettuce leaves also increased from 12.1 to 33.5 mg Cu·kg^{-1}. Using copper sulphate in the doses of 5–75 mg Cu·dm^{-3}, it was found that copper content in lettuce leaves in both experimental years did not exceed 20 mg Cu·kg^{-1}. Tyksiński [1986] quoted the range of copper content in lettuce from 6.1 to 26.1 mg·kg^{-1}, corresponding to Cu doses applied to the peat substrate, where the obtained lettuce yields did not differ and no symptoms of either deficit or excess of copper were found. The quoted range referred to $CuSO_4$ anhydrate. After the application of copper chelate in the doses of 5–75 mg Cu·dm^{-3}, its content in lettuce leaves was significantly higher. Copper content in lettuce not exceeding 20 mg·kg^{-1} was obtained in 2006 using copper chelate in the doses of 5–25 mg Cu·dm^{-3}, and in 2007, when only the dose of 5 mg Cu·dm^{-3} was applied. Chohura et al. [2004] did not find any positive effect of copper chelate on the increase of copper content in tomato leaves. This Cu chelate was used in the growing of greenhouse tomato cultivated in mineral wool with the application of drop fertigation. Copper content in both experimental years, independent of the form and dose of Cu, were very similar.

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

Cu level Poziom Cu mg·dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of copper postać miedzi		mean średnia	form of copper postać miedzi		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
5	14.7	10.4	12.6	12.2	11.2	11.7	12.1
25	19.4	12.7	16.0	22.0	14.5	18.3	17.1
50	28.0	15.6	21.8	27.1	15.9	21.5	21.6
75	49.2	17.1	33.1	50.7	17.1	33.9	33.5
Mean – Średnia	27.8	13.9		28.0	14.7		
Mean for years Średnia dla lat	20.9			21.3			
Mean for form Średnia dla postaci	Chelate – Chelat – 27.9			Sulphate – Siarczan – 14.3			

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 – 1.56, B – 2.20, C – n.s. – r.n., A×C – n.s. – r.n., B×C – n.s. – r.n., A×B×C – n.s. – r.n.

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

Cu level Poziom Cu mg·dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of copper postać miedzi		mean średnia	form of copper postać miedzi		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
5	98.2	189.1	143.6	147.3	142.6	144.9	144.3
25	88.3	186.4	137.4	133.9	172.4	153.2	145.3
50	89.1	179.1	134.1	115.7	244.3	180.0	157.2
75	91.1	188.6	139.9	122.0	195.8	158.9	149.4
Mean – Średnia	91.7	185.8		129.8	188.8		
Mean for years Średnia dla lat	138.7			159.3			
Mean for form Średnia dla postaci	Chelate – Chelat – 110.7			Sulphate – Siarczan – 187.3			

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 – 7.13, B – n.s. – r.n.. C – 7.13, A×C – 10.07, B×C – 14.26, A×B×C – 20.17

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

Cu level Poziom Cu mg·dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of copper postać miedzi		mean średnia	form of copper postać miedzi		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
5	190.5	307.9	249.2	192.8	303.2	248.0	248.6
25	170.1	313.2	241.6	178.3	385.9	282.1	261.9
50	194.9	313.0	253.9	162.0	393.4	277.7	265.8
75	179.1	323.1	251.1	127.8	434.3	281.1	266.1
Mean – Średnia	183.6	314.3		165.2	379.2		
Mean for years Średnia dla lat	249.0			272.2			
Mean for form Średnia dla postaci	Chelate – Chelat – 174.4			Sulphate – Siarczan – 346.8			

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 – 4.90, B – 6.94. C – 4.90, A×C – 6.94, B×C – 9.81, A×B×C – 13.87

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

Cu level Poziom Cu mg·dm^{-3}	Year – Rok 2006			Year – Rok 2007			Mean for levels Średnia dla poziomów
	form of copper postać miedzi		mean średnia	form of copper postać miedzi		mean średnia	
	chelate chelat	sulphate siarczan		chelate chelat	sulphate siarczan		
5	180.7	163.7	172.2	206.6	131.2	168.9	170.6
25	190.9	145.3	168.1	215.7	147.4	181.5	174.8
50	189.4	134.3	161.8	177.2	164.2	170.7	166.3
75	195.8	149.9	172.9	190.9	156.7	173.8	173.3
Mean – Średnia	189.2	148.3		197.6	149.9		
Mean for years Średnia dla lat	168.8			173.7			
Mean for form Średnia dla postaci	Chelate – Chelat – 193.4			Sulphate – Siarczan – 149.1			

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 – 7.37, B – n.s. – r.n., C – n.s.– r.n., A×C – n.s. – r.n., B×C – n.s. – r.n., A×B×C – 20.84

Zinc content in lettuce, depending on the form and dose of copper, are illustrated in table 3. Lettuce fertilized with the sulphate form of Cu content contained significantly more zinc than when fertilized with the chelated form. Differentiated doses of copper did not exert any effect on zinc content in the lettuce.

Manganese content in lettuce leaves, depending on the form and dose of copper, is presented in table 4. Significant effect on manganese content was exerted by the form of the applied copper. Manganese content in lettuce fertilized with copper sulphate was two times higher than in the lettuce fertilized with copper chelate.

Analysis of the effect of copper doses on the content of manganese in lettuce leaves indicated that after the application of the lowest dose of copper, i.e. of 5 mg $Cu \cdot dm^{-3}$, the content of manganese was the lowest, significantly lower than after the application of the doses: 25–75 mg $Cu \cdot dm^{-3}$.

Iron content in lettuce leaves, depending on the form and dose of copper, is shown in table 5. Only the form of the applied copper exerted a significant effect. After the application of the chelated Cu form, the iron content was significantly higher than after the application of copper sulphate. Tyksiński [1993] found that the copper doses did not exert any effect on the contents of manganese, zinc and iron in lettuce grown in peat. The present work has confirmed these regularities.

CONCLUSIONS

1. Lettuce fertilized with copper sulphate gave a higher yield than lettuce fertilized with copper chelate. Using the mineral and the chelated forms of copper in the range of doses from 5 to 50 mg $Cu \cdot dm^{-3}$, the obtained yields did not differ.

2. The mean copper content in lettuce, after the application of the chelated Cu form, was twice higher than after the use of the mineral Cu form. An admissible content of copper in lettuce leaves (i.e. below 20 mg $Cu \cdot kg^{-1}$) was found after the application of 5 mg $Cu \cdot dm^{-1}$ in the form of Cu chelate and after the doses of 5–75 mg $Cu \cdot kg^{-1}$ in the form of copper sulphate.

3. After the application of copper chelate, iron content was higher than after the use of copper sulphate, while after the application of zinc and manganese, the iron content was lower.

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

Streszczenie. W doświadczeniach wazonowych wiosennych (2006 i 2007 r.) porównano wpływ chelatowej i mineralnej postaci miedzi na plonowanie sałaty oraz zawartość Cu, Zn, Mn i Fe w liściach. Rośliny uprawiano w podłożu torfowym, do którego wprowadzono dawki Cu: 5, 25, 50 i 75 mg·dm^{-3}. Większą masę główek sałaty uzyskano po zastosowaniu mineralnej formy miedzi. W zakresie dawkowania 5–50 mg Cu·dm^{-3} średnie plony sałaty nie różniły się. W drugim roku badań zastosowanie chelatu miedzi w dawce 75 mg·dm^{-3} spowodowało dużą redukcję plonu. Zawartość miedzi w sałacie po zastosowaniu chelatu miedzi była dwa razy większa niż po zastosowaniu siarczanu miedzi. Po zastosowaniu chelatu miedzi – zawartość żelaza była większa niż po zastosowaniu siarczanu miedzi, natomiast cynku i manganu była mniejsza.

Słowa kluczowe: sałata, chelat i siarczan miedzi, plon, mikroskładnik

Accepted for print – Zaakceptowano do druku: 27.06.2008