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# EFFECT OF CHELATED AND MINERAL FORMS OF MICRONUTRIENTS ON THEIR CONTENT IN LEAVES AND THE YIELD OF LETTUCE. PART I. MANGANESE

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**Abstract**. In pot experiments with lettuce, the effect of chelated and mineral forms of manganese on the fresh matter of plants and on the content of Mn, Cu, Zn and Fe in lettuce leaves were compared. Lettuce plants were grown in a peat substrate where the manganese content was differentiated in four levels: 10, 20, 30, and 60 mg $Mn \cdot dm^{-3}$. Independent of the form of the applied manganese, no differences were found in fresh matter of lettuce heads at manganese levels of 10 to 30 mg $Mn \cdot dm^{-3}$ substrate. When the plants were nourished with the mineral form of manganese, then in comparison with the chelated form of manganese, the content of manganese in lettuce leaves was higher. The differentiated fertilization with manganese exerted an effect on the nutritional status of plants with copper, zinc and iron. After the application of chelated manganese, there was more copper and iron in the lettuce, but a lesser amount of zinc than in case of manganous sulphate application. The increase of manganese content in the substrate caused an increase of this component in the plants.

**Key words**: lettuce, chelate, sulphate manganese, micronutrients

## INTRODUCTION

The intake of manganese by plants depends among others on the species, genus, reaction and substrate moisture, on the oxidoreductive potential, concentration and form in which manganese and the remaining macro- and micronutrients occur [Kabata-Pendias and Pendias 1999, Łabętowicz and Rutkowska 2001, Grzyś 2004].

In horticultural plant fertilization, both mineral and chelated compounds are used as the source of micronutrients. Metallic micronutrients used in mineral forms are transferred easier than the chelated ones into forms not accessible to plants, particularly in substrates with pH exceeding the value of 6.5. In horticultural cultivations, most fre-

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quently iron chelates are used which has been well documented in scientific literature [Demeyer et al. 2001, Broschat and Moore 2004, Broschat and Elliott 2005, Chohura et al. 2006 and 2007, Kołota et al. 2006]. However, as indicated by the studies of Tyksiński and Komosa [2007], some carriers used for the production of chelates can exert an unfavourable effect on plants. This dependence refers mainly to the use of chelates in traditional horticultural substrates in which the recommended micronutrient doses exceed many times their concentrations recommended for hydroponic cultures.

In the subjective literature, there is no information referring to the more favourable effect of manganese chelate on the yield and chemical composition of plants in comparison with the mineral forms of this component.

The objective of this work was the comparison of effect of the chelated and mineral forms of manganese on the fresh matter of lettuce heads and on the content of micronutrients in the leaves.

## MATERIAL AND METHODS

In the years 2006–2007, three experiments with head lettuce of 'Michalina' cultivar were carried out. In the first year, plants were grown in spring and autumn, while in the second year, the cultivation was done in spring only.

The experimental factors included:

1. manganese forms: chelate of Mangan Forte 14 from Intermag Co. [Mn(II)EDTA+Mn(II)DTPA], manganous sulphate ($MnSO_4 \cdot H_2O$),
2. manganese levels – 4 doses: 10, 20, 30 and 60 mg $Mn \cdot dm^{-3}$

The substrate was prepared of raised peat which 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, sufficient contents of Ca – 2045, Mg – 160, $S\text{-}SO_4$ – 25 $mg \cdot dm^{-3}$ were found in the substrate, therefore, those components were not supplemented. The remaining macro- and micronutrients in the substrate were supplemented to the contents ($mg \cdot dm^{-3}$): N – 180, P – 140, K – 220, Ca – 2045, Mg – 160, Zn – 20, Cu – 5, B – 1, Mo – 1. Manganese was applied according to the assumptions accepted in the experiment after the consideration of its initial content which in the peat after liming was 2.7 mg $Mn \cdot dm^{-3}$. Lettuce seeds were sown on the 21st of March in both experimental years and on the 22nd of August in 2006. The seeds were single-grain sown into boxes of 10 $dm^3$ capacity filled with raised peat (Lithuania) previously limed with 5g $\cdot dm^{-3}$ $CaCO_3$ and enriched with Azofoska in the amount of 1.5 $g \cdot dm^{-3}$. Lettuce seedlings in the phase of 2 proper leaves were planted on the 13th of April and on the 15th of September into containers of 6 $dm^3$ capacity filled with adequately prepared substrate. Each combination included 4 containers as replications with 4 plants in each container.

In the vegetation period, the plants were irrigated to 70% water capacity of peat determined on the basis of Wahnschaff's cylinders. Lettuce harvest was carried out on the 16th of May and on the 30th of October. After the cutting of plants, they were weighed and dried in extractor drier and homogenized. In the plant material, the content of

micronutrients was determined by ASA method after wet mineralization in a mixture of $HNO_3$ and $HClO_4$ acids in 3:1 proportion.

Results of plant fresh matter yield and the content of micronutrients in lettuce were statistically estimated. After the identification of significant differences, the mean values were grouped according to Newman Keul's test at the significance level of $\alpha = 0.05$.

## RESULTS

Mean results from 2-year experiment carried out in spring indicate that the fresh matter of lettuce heads depended on the form and dose of the applied manganese and on the year of studies (tab. 1). Significantly higher plant fresh matter weight was obtained after the application of manganese in the mineral form than in the chelated form. Independent of the manganese form and on the year of studies, a significantly lower matter of lettuce heads was found after the application of manganese at the level of 60 mg $Mn \cdot dm^{-3}$ of substrate. Furthermore, significant differences have been proven in the fresh matter of lettuce heads between the particular years of studies. In 2007, on the average, a higher matter of plants by about 15% was obtained in comparison with the year 2006. It must be stressed that in the particular years, plant reaction to the forms and doses of manganese was differentiated.

Table 1. Fresh matter of lettuce grown in spring (g ·container$^{-1}$ f.m.), depending on the form and the dose of manganese in the substrate.

Tabela 1. Świeża masa sałaty uprawianej wiosną (g·pojemnik$^{-1}$ś.m.), w zależności od formy i poziomu manganu w podłożu

| Mn dose Dawka Mn mg·dm$^{-3}$ | Year – Rok 2006 | | | Year – Rok 2007 | | | Mean for dose Średnia dla dawki |
|---|---|---|---|---|---|---|---|
| | form of manganese forma manganu | | mean średnia | form of manganese forma manganu | | mean średnia | |
| | chelate chelatowa | mineral mineralna | | chelate chelatowa | mineral mineralna | | |
| 10 | 439.7 | 457.5 | 448.6 | 552.2 | 588.0 | 570.1 | 509.4 |
| 20 | 504.7 | 491.2 | 498.0 | 579.7 | 611.7 | 595.7 | 546.9 |
| 30 | 507.0 | 457.5 | 482.2 | 540.2 | 682.0 | 611.1 | 546.7 |
| 60 | 491.7 | 445.0 | 468.4 | 247.7 | 681.2 | 464.5 | 466.4 |
| Mean Średnia | 485.8 | 462.8 | | 480.0 | 640.7 | | |
| Mean for years Średnia dla lat | 474.3 | | | 560.4 | | | |
| Mean for form Średnia dla form | chelate – chelatowa – 482.9 | | | mineral – mineralna – 551.8 | | | |

Factors – Czynniki: A – forms – formy, B – doses – dawki, C – years – lata,
n.s. – not significant, r.n. – różnice nieistotne.
$LSD_{0.05}$for; $NIR_{0.05}$dla:
A – 26.7, B – 37.7, C – 26.7, A×C – 37.7, B×C – 53.3, A×B×C – 75.4.

In spring 2006, no significant differences were found in fresh matter of lettuce either under the influence of the applied form of manganese or due to the manganese level in the substrate in the range from 10 to 60 mg Mn·dm$^{-3}$. In 2007 lettuce with a greater weight was obtained under the influence of fertilization with manganese in the mineral form than in the chelated form. In the same year, the increase of manganese level in the substrate to 60 mg Mn·dm$^{-3}$ in the form of chelate caused a significant decrease of fresh matter of lettuce heads, while the application of manganese in the form of sulphate above the level of 20 mg Mn·dm$^{-3}$ substrate caused in effect a significant matter increase. On the other hand, Tyksiński [1984], after the application of the dose of 60 mg Mn·dm$^{-3}$ substrate, in mineral form, found a reduction in the yield.

In autumn 2006, fresh matter of lettuce heads was lower than in spring, whereby a significantly greater weight of plants was obtained when chelate was the source of manganese (tab. 6). Similarly as in spring of that year of studies, the levels of the component in the range from 10 to 60 mg Mn·dm$^{-3}$ did not exert any effect on the mean matter of lettuce heads, independent of the form of the applied manganese.

The contents of manganese in lettuce depending on the form and dose of the component are shown in tables 2 and 6. In all three experiments, a greater content of manganese was found in plants after the use of the mineral manganese form for fertilization. In turn, the study results of Chohura et al. [2004] indicate that a greater manganese content in the leaves of tomatoes grown in rockwool occurred after the use of the chelated form of manganese in the nutrient than after the application of the mineral form.

Table 2. Manganese content (mg·kg$^{-1}$ d.m.) in lettuce grown in spring depending on the form and dose of manganese in the substrate

Tabela 2. Zawartość manganu (mg·kg$^{-1}$s.m.) w sałacie uprawianej wiosną, w zależności od formy i poziom manganu w podłożu

| Mn dose Dawka Mn mg·dm$^{-3}$ | Year – Rok 2006 | | | Year – Rok 2007 | | | Mean for dose Średnia dla dawki |
|---|---|---|---|---|---|---|---|
| | form of manganese forma manganu | | mean średnia | form of manganese forma manganu | | mean średnia | |
| | chelate chelatowa | mineralmi-neralna | | chelate chelatowa | mineral mineralnaa | | |
| 10 | 155.6 | 251.2 | 203.4 | 157.1 | 329.1 | 243.1 | 223.3 |
| 20 | 191.2 | 307.9 | 249.6 | 185.2 | 435.6 | 310.4 | 280.0 |
| 30 | 216.9 | 336.9 | 276.9 | 210.6 | 464.5 | 337.5 | 307.2 |
| 60 | 290.4 | 348.9 | 319.7 | 244.0 | 485.4 | 364.7 | 342.2 |
| Mean Średnia | 213.5 | 311.2 | | 199.2 | 428.6 | | |
| Mean for years Średnia dla lat | 262.4 | | | 313.9 | | | |
| Mean for form Średnia dla form | chelate – chelatowa – 206.4 | | | mineral – mineralna – 369.9 | | | |

Factors – Czynniki: A – forms – formy, B – doses – dawki, C – years – lata,
n.s. – not significant , r.n. – różnice nieistotne.
$LSD_{0.05}$for; $NIR_{0,05}$dla:
A – 6.9, B – 9.8, C – 6.9, A×C – 9.8, B×C – n.s. – r.n., A×B×C – 19.6.

Table 3. Copper content (mg·kg$^{-1}$ d.m.) in lettuce grown in spring, depending on the form and dose of manganese in the substrate

Tabela 3. Zawartość miedzi (mg·kg$^{-1}$s.m.) w sałacie uprawianej wiosną, w zależności od formy i poziomu manganu w podłożu

| Mn dose Dawka Mn mg·dm$^{-3}$ | Year – Rok 2006 | | | Year – Rok 2007 | | | Mean for dose Średnia dla dawki |
|---|---|---|---|---|---|---|---|
| | form of manganese forma manganu | | mean średnia | form of manganese forma manganu | | mean średnia | |
| | chelate chelatowa | mineral mineralna | | chelate chelatowa | mineral mineralna | | |
| 10 | 14.27 | 10.33 | 12.30 | 11.30 | 15.27 | 13.28 | 12.79 |
| 20 | 14.92 | 10.43 | 12.67 | 13.90 | 12.12 | 13.01 | 12.84 |
| 30 | 15.57 | 9.60 | 12.59 | 13.27 | 11.25 | 12.26 | 12.42 |
| 60 | 18.70 | 8.28 | 13.49 | 16.45 | 10.55 | 13.50 | 13.49 |
| Mean Średnia | 15.87 | 9.66 | | 13.73 | 12.30 | | |
| Mean for years Średnia dla lat | | 12.76 | | | 13.02 | | |
| Mean for form Średnia dla form | chelate – chelatowa – 14.80 | | | mineral – mineralna – 10.98 | | | |

Factors – Czynniki: A – forms – formy, B – doses– dawki, C – years – lata,
n.s. – not significant , r.n. – różnice nieistotne.
$LSD_{0.05}$for; $NIR_{0.05}$dla:
A – 0.92, B – n.s. – r.n., C – n.s. – r.n., A×C – 1.29, B×C – n.s. – r.n., A×B×C – n.s. – r.n.

When manganese in the substrate increased, both in spring and in autumn, then increased also significantly the content of this component in lettuce. This dependence was shown for both sources of manganese. In experiments carried out in spring after the application of manganese in the form of chelate, in the particular combinations, the manganese contents in lettuce were similar with the exception of the plants grown in substrate with 60 mg Mn·dm$^{-3}$. At this level of manganese, a significantly higher Mn content in plants was obtained in the first year of studies. On the other hand, when sulphate was the source of manganese, independent of the dose of this component, a significantly greater Mn content in lettuce was obtained in the second year of studies.

Comparison of the mean manganese contents in plants grown in spring and autumn indicated a smaller Mn content in the autumn cultivation. Similar dependences in experiments with lettuce were found by Tyksiński [1992] and Michałojć [2000]. Manganese contents obtained in lettuce grown in two experiments in spring were in the range from 155.60 to 485.27 mg Mn·kg$^{-1}$ d.m., and in autumn, they were from 122.72 to 431.50 mg Mn·kg$^{-1}$ d.m.

Generally, they are in the interval recommended by Tyksiński [1992]. The author reported that the content of manganese in a healthy lettuce grown in peat is 220-720 mg Mn·kg$^{-1}$ d.m.

Significantly lower contents of manganese in lettuce were accepted as the optimal ones by de Kreij et al. [1990]: 554.3 – 108.6 mg Mn·kg$^{-1}$. Kabata-Pendias and Pendias [1999] suggested the following values: 48 – 107 mg Mn·kg$^{-1}$ d.m. Furthermore, Winsor

and Adams [1987] and Tyksiński [1992] called attention to the differences between cultivars regarding the content of manganese in lettuce leaves.

Data contained in tables 3, 4, 5 i 7 indicate that differentiated fertilization of lettuce with manganese exerted an effect on plant nutritional status in reference to copper, zinc and iron.

Table 4. Zinc content (mg·kg$^{-1}$ d.m.) in lettuce grown in spring, depending on the form and dose of manganese in the substrate

Tabela 4. Zawartość cynku (mg·kg$^{-1}$s.m.) w sałacie uprawianej wiosną, w zależności od formy i poziomu manganu w podłożu

| Mn dose Dawka Mn mg·dm$^{-3}$ | Year – Rok 2006 | | | Year – Rok 2007 | | | Mean for dose Średnia dla dawki |
|---|---|---|---|---|---|---|---|
| | form of manganese forma manganu | | mean średnia | form of manganese forma manganu | | mean średnia | |
| | chelate chelatowa | mineral mineralna | | chelate chelatowa | mineral mineralna | | |
| 10 | 110.2 | 177.3 | 143.8 | 108.0 | 198.4 | 153.2 | 148.5 |
| 20 | 113.4 | 189.1 | 151.3 | 87.0 | 204.6 | 145.8 | 148.5 |
| 30 | 90.9 | 202.3 | 146.6 | 93.0 | 220.9 | 156.9 | 151.8 |
| 60 | 98.4 | 203.3 | 150.8 | 133.0 | 216.3 | 174.6 | 162.7 |
| Mean Średnia | 103.2 | 193.0 | | 105.3 | 210,0 | | |
| Mean for years Średnia dla lat | 148.1 | | | 157.6 | | | |
| Mean for form Średnia dla form | chelate – chelatowa – 104.2 | | | mineral – mineralna – 201.5 | | | |

Factors – Czynniki: A – forms – formy, B – doses – dawki, C – years – lata,
n.s. – not significant , r.n. – różnice nieistotne.
$LSD_{0.05}$for; $NIR_{0.05}$dla:
A – 6.0, B – 8.5, C – 6.6, A×C – n.s. – r. n., B×C – n.s. – r.n., A×B×C – 16.9.

It was found that copper content in plants depended on the form of the applied manganese in plants. When chelate was the source of manganese, there was more copper in plants in comparison with the mineral form. This dependence was statistically confirmed in all experiments.

Mean values from both experiments carried out in spring indicate that the doses of the applied manganese and the years of studies had no effect on the content of copper in lettuce.

However, with the increase of manganese dose in the chelated form, there increased the content of copper in plants. In autumn, a significantly greater copper content was found in plants fertilized with manganese in the chelated form to the level of 60 mg Mn·dm$^{-3}$ of substrate. Mean copper contents in lettuce leaves were contained in the range accepted as the optimal ones by Tyksiński [1992].

Table 5. Iron content (mg·kg$^{-1}$ d.m.) in lettuce grown in spring, depending on the form and dose of manganese in the substrate

Tabela 5. Zawartość żelaza (mg·kg$^{-1}$s.m.) w sałacie uprawianej wiosną, w zależności od formy i poziomu manganu w podłożu

| Mn dose Dawka Mn mg·dm$^{-3}$ | Year – Rok 2006 | | | Year – Rok 2007 | | | Mean for dose Średnia dla dawki |
|---|---|---|---|---|---|---|---|
| | form of manganese forma manganu | | mean średnia | form of manganese forma manganu | | mean średnia | |
| | chelate chelatowa | mineral mineralna | | chelate chelatowa | mineral mineralna | | |
| 10 | 220.7 | 173.1 | 196.9 | 175.8 | 190.1 | 182.9 | 189.9 |
| 20 | 221.4 | 163.7 | 192.6 | 172.8 | 204.3 | 188.6 | 190.6 |
| 30 | 191.4 | 155.9 | 173.6 | 193.9 | 201.6 | 197.8 | 185.7 |
| 60 | 221.0 | 147.3 | 184.2 | 235.3 | 169.7 | 202.5 | 193.3 |
| Mean Średnia | 213.6 | 160.0 | | 194.4 | 191.4 | | |
| Mean for years Średnia dla lat | 186.8 | | | 192.9 | | | |
| Mean for form Średnia dla form | chelate – chelatowa – 204.0 | | | mineral – mineralna – 175.7 | | | |

Factors – Czynniki: A – forms – formy, B – doses – dawki, C – years – lata,
n.s. – not significant , r.n. – różnice nieistotne.
$LSD_{0.05}$for; $NIR_{0,05}$dla:
A – 9.6, B – n.s. – r.n., C – n.s. – r.n., A×C – 13.5, B×C – n.s. – r.n., A×B×C – n.s. – r.n.

Table 6. Fresh matter and content of manganese in lettuce grown in autumn, depending on the form and dose of manganese in the substrate

Tabela 6. Świeża masa i zawartość manganu w sałacie uprawianej jesienią w zależności od formy i poziomu manganu w podłożu

| Mn dose Dawka Mn mg·dm$^{-3}$ | Yield (g·container$^{-1}$ f.m.) Plon (g·pojemnik$^{-1}$ ś.w.) | | | mg Mn·kg$^{-1}$ d.m. mg Mn·kg$^{-1}$ s.m. | | |
|---|---|---|---|---|---|---|
| | form of manganese forma manganu | | mean średnia | form of manganese forma manganu | | mean średnia |
| | chelate chelatowa | mineral mineralna | | chelate chelatowa | mineral mineralna | |
| 10 | 399.7 | 382.5 | 391.1 | 129.5 | 223.7 | 176.6 |
| 20 | 408.7 | 351.2 | 380.0 | 122.7 | 336.8 | 229.7 |
| 30 | 402.5 | 343.5 | 373.0 | 167.7 | 378.6 | 273.1 |
| 60 | 372.7 | 327.0 | 349.9 | 264.7 | 431.5 | 348.1 |
| Mean Średnia | 395.9 | 351.1 | | 171.2 | 342.6 | |

Factors – Czynniki: A – forms – formy, B – doses – dawki,
n.s. – not significant , r.n. – różnice nieistotne.
Yield – Plon; $LSD_{0.05}$ for; $NIR_{0,05}$ dla: A – 24.3, B – n.s. – r.n., A×B – n.s. – r.n.
Content of Mn – Zawartość Mn; $LSD_{0.05}$ for; $NIR_{0,05}$ dla: A – 14.6, B – 20.7, A×B – 29.3.

Plants fertilized with manganese in the chelated form had the zinc content smaller by about 100 mg Zn·kg$^{-1}$ d.m. than plants nourished by manganese in the sulphate form. In spring, independent of manganese form and the year of studies, significantly higher mean contents of zinc were determined in the plants grown in the combination with 60 mg Mn·dm$^{-3}$ of substrate. After the application of this dose of manganese in the chelated form, only in the second year of studies, there followed an increase of zinc content in the plants in comparison with the remaining combinations. When sulphate was the source of manganese, a significantly smaller zinc content was found only in the first year of studies in the plants grown in the substrate of 10 mg Mn·dm$^{-3}$, than with the levels of 30 and 60 mg Mn·dm$^{-3}$ of substrate. In autumnal experiment, independent of the Mn form and in the case when manganese was applied in the mineral form in the dose leading to the level of 60 mg Mn·dm$^{-3}$, the content of zinc in lettuce was the smallest. After the use of manganese in the chelated form, the content of zinc in plants grown in substrates with manganese levels from 20 to 60 mg Mn·dm$^{-3}$ was smaller. Chohura et al. [2004] found a greater zinc content in tomato leaves only in the measurement terms in one year of studies, after the application of manganese in the chelated form in comparison with the mineral form.

Table 7. Content of copper, zinc and iron in lettuce grown in autumn, depending, on the form and dose of manganese in the substrate

Tabela 7. Zawartość miedzi, cynku i żelaza w sałacie uprawianej jesienią w zależności od formy i poziomu manganu

| Mn dose<br>Dawka Mn<br>mg·dm$^{-3}$ | mg Cu·kg$^{-1}$ d.m.<br>mg Cu·kg$^{-1}$ s.m. | | | mg Zn·kg$^{-1}$ d.m.<br>mg Zn·kg$^{-1}$ s.m. | | | mg Fe·kg$^{-1}$ d.m.<br>mg Fe·kg$^{-1}$ s.m. | | |
|---|---|---|---|---|---|---|---|---|---|
| | form of manganese<br>forma manganu | | mean<br>średnia | form of manganese<br>forma manganu | | mean<br>średnia | form of manganese<br>forma manganu | | mean<br>średnia |
| | chelate<br>chelatowa | mineral<br>mineralna | | chelate<br>chelatowa | mineral<br>mineralna | | chelate<br>chelatowa | mineral<br>mineralna | |
| 10 | 14.52 | 11.55 | 13.04 | 95.9 | 195.6 | 145.8 | 187.6 | 144.0 | 165.8 |
| 20 | 14.35 | 10.90 | 12.62 | 75.8 | 204.0 | 139.9 | 156.8 | 154.0 | 155.4 |
| 30 | 15.55 | 11.90 | 13.72 | 73.0 | 189.6 | 131.3 | 183.7 | 145.5 | 164.6 |
| 60 | 18.25 | 11.15 | 14.70 | 88.2 | 148.4 | 118.3 | 196.0 | 126.2 | 161.1 |
| Mean<br>Średnia | 15.67 | 11.37 | | 83.2 | 184.4 | | 181.0 | 142.4 | |

Factors – Czynniki: A – forms – formy, B – doses – dawki,
n.s. – not significant , r.n. – różnice nieistotne.
Content of Cu – zawartość Cu; $LSD_{0.05}$ for; $NIR_{0.05}$ dla: A – 0.54, B – 0.76, A×B – 1.07.
Content of Zn – zawartość Zn; $LSD_{0.05}$ for; $NIR_{0.05}$ dla: A – 7.7, B – 10.9, A×B – 15.5.
Content of Fe – zawartość Fe; $LSD_{0.05}$ for; $NIR_{0.05}$ dla: A – 10.7, B – n.s. – r.n., A×B – 21.5.

The mean content of iron in lettuce depended only on the form of the applied manganese. In all three experiments, a higher iron content was shown by plants which were given manganese in the chelated form in comparison with plants nourished by the mineral Mn form. Increasing amounts of manganese supplied to the substrate did not show

any effect on the iron content in plants. The same interrelation between these micronutrients was also found by Tyksiński [1993].

## CONCLUSIONS

1. When manganese content in the substrate was from 10 to 30 mg·dm$^{-3}$, as far as the fresh matter content in lettuce heads is concerned, manganese chelate and manganese sulphate have shown to be equivalent sources of manganese.
2. The highest fresh matter of lettuce heads in a peat substrate was obtained when manganese content was from 10 to 30 mg Mn·dm$^{-3}$ substrate, independent of the applied manganese form.
3. A higher manganese content in plants were found when the plants were fertilized with the mineral form on manganese in comparison with the chelated form.
4. After the application of manganese chelate, it was found that in lettuce, there was more copper and iron, while the content of zinc was smaller than the application of the mineral form of manganese.
5. Increasing doses of manganese did not exert any effect on the content of iron in the lettuce.

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

**Streszczenie.** W doświadczeniach wazonowych z sałatą porównano wpływ chelatowej i mineralnej formy manganu na świeżą masę roślin i zawartość Mn, Cu, Zn i Fe w liściach. Rośliny uprawiano w podłożu torfowym, w którym zawartość manganu zróżnicowano do czterech dawek: 10, 20, 30 i 60 mg $Mn \cdot dm^{-3}$. Niezależnie od formy zastosowanego manganu, nie stwierdzono istotnych różnic w świeżej masie główek sałaty przy zawartości składnika w podłożu w zakresie od 10 do 30 mg $Mn \cdot dm^{-3}$. Przy żywieniu roślin mineralną formą manganu w porównaniu z formą chelatową uzyskano większą zawartość manganu w roślinach. Zróżnicowane nawożenie manganem wpłynęło na stan odżywienia roślin miedzią, cynkiem i żelazem. Po zastosowaniu chelatu manganu stwierdzono w sałacie więcej miedzi i żelaza, a mniej cynku niż po zastosowaniu siarczanu manganu. Zwiększenie ilości manganu w podłożu powodowało wzrost ilości składnika w roślinach.

**Słowa kluczowe**: sałata, chelat i siarczan manganu, mikroelementy

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