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EFFECT OF FERTILIZATION WITH Fe CHELATES ON THE STATE OF IRON NUTRITION OF GREENHOUSE TOMATO

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Abstract

A greenhouse experiment aimed at investigating the effect of four chelates, differing in percentage of Fe content and the kind of Fe bonding ligand: Fe 8 Forte (EDTA+ +HEEDTA), Fe 9 Premium (DTPA), Fe 13 Top (EDTA) and Librel Fe DP7 (DTPA), on the state of iron nutrition of Merkury F_1 cultivar greenhouse tomato grown traditionally in peat substrate. The second factor was iron content in the growing medium, which was established to reach the following levels: 50, 75 and 100 mg $Fe \cdot dm^{-3}$, while in the control object Fe values ranged 17.9 $Fe \cdot dm^{-3}$ (after peat liming). The experiment was established in a two-factorial design with three replications including four plants cultivated on one plot. The iron content was assayed in plant index parts according to the ASA method. On the basis of the results, significant differences were found in the state of greenhouse tomato nutrition under the influence of the examined iron chelates. The highest content of iron in tomato leaves was determined when chelate Fe 9 Premium (DTPA) was used, which points to the fact that it was the best source of Fe. The lowest iron level was recorded after the application of Fe 13 Top (EDTA). The highest mean Fe content for the years and dates of analyses appeared in leaves of plants cultivated in the growing medium containing 75 mg $Fe \cdot dm^{-3}$. In June, after the plants began to yield, there was a considerable decrease in the Fe content in plant index parts in comparison to the stage of fruit maturation and the end of yielding. The study did not demonstrate any symptoms of phytotoxicity or visible disorders regarding tomato growth and development due to the examined Fe chelates introduced in the doses of 32.1, 57.1 and 82.1 mg $Fe \cdot dm^{-3}$ to the substrate, whose initial Fe concentration after peat liming was on average 17.9 mg $Fe \cdot dm^{-3}$.

Key words: greenhouse tomato, fertilization, chelates, index parts, iron uptake.

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WPŁYW NAWOŻENIA CHELATOWMI FORMAMI Fe NA STAN ODŻYWIENIA POMIDORA SZKLARNIOWEGO ŻELAZEM

Abstrakt

W doświadczeniu szklarniowym badano wpływ czterech chelatów, różniących się procentową zawartością żelaza oraz rodzajem ligandu, jakim skompleksowano ten składnik: Fe 8 Forte (EDTA+HEEDTA), Fe 9 Premium (DTPA), Fe 13 Top (EDTA) i Librel Fe DP7 (DTPA), na stan odżywienia żelazem pomidora szklarniowego odmiany Merkury F_1 uprawianego metodą tradycyjną w substracie torfowym. Drugim czynnikiem badawczym była zróżnicowana zawartość żelaza w podłożu, którą doprowadzono do wartości: 50, 75 i 100 mg $Fe \cdot dm^{-3}$. Doświadczenie założono w układzie dwuczynnikowym, w trzech powtórzeniach. Na jednym poletku uprawiano 4 rośliny. W częściach wskaźnikowych oznaczano całkowitą zawartość żelaza metodą ASA. Stwierdzono istotne różnice w stanie odżywienia pomidora szklarniowego pod wpływem badanych chelatów żelazowych. Najwyższą zawartość żelaza w liściach pomidora odnotowano, gdy źródłem Fe był chelat Fe 9 Premium (DTPA), a najniższą po zastosowaniu Fe 13 Top (EDTA). Najwyższą średnią zawartość żelaza w liściach uprawianych roślin obliczoną dla lat i terminów analiz stwierdzono, gdy zasobność wynosiła 75 mg $Fe \cdot dm^{-3}$. W czerwcu, po rozpoczęciu plonowania roślin, następował znaczny spadek zawartości żelaza w częściach wskaźnikowych pomidora w porównaniu z pozostałmi terminami analiz. W badaniach nie stwierdzono żadnych objawów fitoksyczności, a także widocznych zaburzeń we wzroście i rozwoju pomidora pod wpływem badanych chelatów żelazowych stosowanych w dawkach 32,1, 57,1 i 82,1 mg $Fe \cdot dm^{-3}$ substratu, którego wyjściowa zasobność po odkwaszeniu torfu wynosiła średnio 17,9 mg $Fe \cdot dm^{-3}$.

Słowa kluczowe: pomidor szklarniowy, nawożenie, chelaty, części wskaźnikowe, pobieranie żelaza.

INTRODUCTION

Microelements, especially iron, play an important role in tomato nutrition. According to CHOHURA et al. (2006), the recommended Fe content in greenhouse tomato leaves should be over 60.0 mg $Fe \cdot kg^{-1}$ of dry matter.

This microelement significantly affects the quantity and quality of tomato yield, especially in greenhouses cultivation with a limited volume of the growing medium. A characteristic feature of Fe ions is their ease of transition into the forms hardly available to plants due to chemical sorption. Iron cations Fe^{+2} under aerobic conditions easily change their valence to Fe^{+3}, which makes them less available to plants (GUERINOT, YI 1994).

The problem of providing appropriate Fe nutrition of tomatoes is quite common, although organic growing media, especially those prepared from peat, contain high amounts of humus compounds, which act as natural chelators for cations. Among the causes of limited availability and Fe uptake by plants are excessively high pH, excessive contents of phosphates and carbonates in the growing medium and its excessively high moisture (TIFFIN et al. 1960).

Application of chelate forms featuring good water solubility and low value of dissociation constant (KOMOSA et al. 2005) is of a basic way of preventing as well as to reducing retrogradation of Fe cations in a growing medium. Following such treatment, Fe cations are gradually released to the soil solution and they can be taken up by plants in the form of complexes. According to STUART et al. (1991), chelate Fe fertilizers most often occur as the ligands EDTA (ethylenediaminetetraacetic acid), DTPA (diethylenetriaminepentaacetic acid) or HEEDTA (hydroxyl-2-ethylenediaminetriacetic acid). Persistance of ions and their availability to plants depend on the properties of a chelate compound which complexes Fe cations (HOFFMANN, GÓRECKI 2000).

The purpose of this investigation was to assess the effect of chelates Fe 9 Premium, Fe 8 Forte, Fe 13 Top, Librel Fe DP7 on the state of Fe nutrition of Merkury F_1 cultivar greenhouse tomato grown on peat substrate with the traditional method.

MATERIAL AND METHODS

Growing experiments were conducted in a heated greenhouse in 2006--2007. Transplants of Merkury F_1 cultivar greenhouse tomato were planted on benches into peat substrate, with 50 dm^3 of substrate per plant and 3 plants per 1 m^2. The cultivation started in the 2^{nd} decade of April and finished in the 3^{rd} decade of July. Plants were trained for one stem and five trusses. Peat substrate limed with chalk to pH 5.50, provided by Hartman company, was used as a growing medium. In 2006, the available Fe content after peat liming was reduced from 26.2 to 20.2 $Fe \cdot dm^{-3}$, while in 2007, it fell from 50.2 to 15.4 mg $Fe \cdot dm^{-3}$. Before planting tomatoes, the Fe content in the growing medium was standardized to the values recommended for greenhouse tomatoes by KOMOSA (2005): N – 220, P – 180, K – 350, Ca – 2000, Mg – 200, Mn – 20, Zn – 20, Cu – 5.0, B – 1.5, Mo – 1.5 $mg \cdot dm^{-3}$. In the 2^{nd} decade of July, the plants were additionally fertilized with 5 g N and 10 g K per 1 m^2 of the growing medium

The experiment was established in a two-factorial design including three replications, with four plants per plot. The first factor were chelate fertilizers differing in percentage of Fe content and the kind of ligand they were complexed with, namely: Fe 8 Forte (EDTA+HEEDTA), Fe 9 Premium (DTPA), Fe 13 Top (EDTA) and Librel Fe DP7 (DTPA). The second factor was the Fe content in the growing media, which was established as 50, 75 and 100 mg $Fe \cdot dm^{-3}$. The control treatment involved the growing medium featuring native Fe content.

Fully developed leaves were used as index parts of tomatoes. The samples were collected three times in the course of plant growing period, i.e. in May – before the onset of fruit maturation, in June – at the beginning of yielding, and in July – during full yielding. Plant material, previously dried and ground, was subjected to wet mineralization in a mixture of acids HNO_3:$HClO_4$ 3:1 (v/v). Chemical analyses comprised assays of total Fe content in leaves according to the ASA method. The results were subjected statistical elaboration using analysis and the least significant differences calculated at $p = 0.05$.

RESULTS AND DISCUSSION

Mean values of the results obtained during the entire two-year-investigation, shown in Table 1, proved that the kind of Fe chelate used, as well as its dose *did* significantly differentiate the iron content in index parts of Merkury F_1 cultivar greenhouse tomato. Regardless of the term of analyses, it was possible to state that tomatoes showed of a proper state of nutrition, and the iron content was higher than its minimum value recommended by Chohura and Komosa (2003), equal 60.0 mg Fe kg^{-1} d.m. In another experiment conducted on rockwool as a growing medium, the same authors recorded the iron content in tomato index parts ranging 55-220 mg Fe kg^{-1} d.m. In our own examinations, the mean Fe content in tomato index parts was higher, reaching from 132.1 to 355.8 mg Fe kg^{-1} d.m.

In May, before fruit maturation, the average iron content in leaves of tomato fertilized with Librel Fe DP7 and Fe 9 Premium did not show any significant differences and was considerably higher than the content recorded for the other chelates as well as the control. It was also found that the application of gradually increasing Fe doses contributed to a significant increase in the level of this microelement in tomato leaves as compared to the control. In June, when tomato plants began to yield, the results were quite different. All the means of Fe content determined after the application of particular fertilizers differed significantly and were statistically higher compared to the control. The lowest iron content was recorded in the leaves of plants fertilized with Librel Fe DP7 (156.3 mg Fe$\cdot$$kg^{-1}$ d.m.), while the highest one – after application of Fe 9 Premium (187.0 mg Fe$\cdot$$kg^{-1}$ d.m).

On the last term of analyses, in July, similarly to the results of June, all means for the examined fertilizers were significantly different. The highest Fe content (304.3 mg Fe$\cdot$$kg^{-1}$ d.m.) was assayed in the leaves of plants fertilized with Librel Fe DP7 chelate and the lowest Fe value was obtained for Fe 13 Top (261.6 mg Fe$\cdot$$kg^{-1}$ d.m.).

The state of plant nutrition was also significantly dependent on the iron concentration in the growing medium. The highest Fe mean content in tomato leaves in June and July was recorded in the plants cultivated at a concentration of 75 mg Fe$\cdot$$dm^{-3}$ in peat substrate, while in May – at 100 mg Fe$\cdot$$dm^{-3}$.

Table 1

Iron content in the index part of greenhouse tomato in relation to the kind of chelates and Fe concentration in peat substrate (mean for 2006-2007, mg $Fe \cdot kg^{-1}$ d.m.)

Fe fertilizer	Fe concentration in peat substrate (mg $Fe \cdot dm^{-3}$)			
	50	75	100	mean
	May			
Fe 13 Top (EDTA)	193.8	283.1	272.5	249.8
Fe 8 Forte (EDTA+HEEDTA)	267.9	238.5	252.7	253.0
Librel Fe DP7 (DTPA)	267.5	279.1	320.9	289.1
Fe 9 Premium (DTPA)	317.4	276.5	269.7	287.9
Mean	261.6	269.3	278.9	
Control				191.9
$LSD_{p=0.05}$ for: fertilizer 3.7 dose 3.2 interaction 9.1				
	June			mean
Fe 13 Top (EDTA)	193.6	192.1	161.0	182.2
Fe 8 Forte (EDTA+HEEDTA)	181.7	195.4	153.8	176.9
Librel Fe DP7 (DTPA)	145.5	181.3	142.1	156.3
Fe 9 Premium (DTPA)	193.4	193.5	174.2	187.0
Mean	178.5	190.5	157.8	
Control				132.1
$LSD_{p=0.05}$ for: fertilizer 3.3 dose 2.8 interaction 8.2				
	July			mean
Fe 13 Top (EDTA)	159.2	333.7	292.1	261.6
Fe 8 Forte (EDTA+HEEDTA)	327.6	342.8	203.0	291.1
Librel Fe DP7 (DTPA)	203.9	355.8	353.4	304.3
Fe 9 Premium (DTPA)	269.3	331.2	253.1	284.5
Mean	240.0	340.9	275.4	
Control				262.5
$LSD_{p=0.05}$ for: fertilizer 4.1 dose 3.6 interaction 10.1				

In the latter term, an important role was also played by the interaction between the kind of fertilizers and their doses. The most satisfactory Fe nutritional state was recorded for Fe 8 Forte and Fe 9 Premium at the Fe concentration equal 50 mg in the growing medium, while in the case of Librel Fe DP7 it was 100 mg Fe·dm^{-3}. The lowest mean content of total iron in tomato index parts in May and June was determined for the control treatment, and in July, when the plants were grown in the medium of initial Fe concentration at the level of 50 mg Fe·dm^{-3}.

In June, on the second term of analyses, a considerable decrease in the mean content of total iron in tomato leaves was observed. This phenomenon could have been caused by the increased plant demand for that component at the beginning of yielding. A similar reaction was reported by Kowalczyk et al. (2008) regarding tomato cultivation on rockwool, as well as Komosa et al. (2005).

The results of this study indicate that the highest mean iron content, regardless of the term of analyses, occurred in the leaves of plants fertilized with Fe 9 Premium chelate (253.1 mg Fe·kg^{-1} d.m.). Similar results (249.9 mg Fe·kg^{-1} d.m.) were obtained for Librel Fe DP7 (Figure 1). The

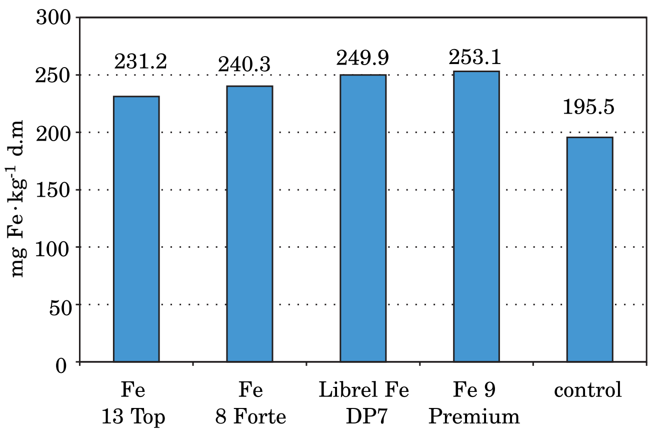

Fig. 1. Effect of the type of iron chelate on Fe content in index part of greenhouse tomato (mean for 2006-2007, mg Fe·kg^{-1} d.m.)

worst state of Fe nutrition was observed after application of Fe 13 Top, which could have resulted from the pH of the growing medium (5.50 at the beginning of cultivation). In the course of tomato production, owing to plant watering with tap water, the reaction of the growing medium gradually increased and when the experiment was terminated, it ranged between 6.50-6.80. According to Komosa et al. (2005) EDTA protects iron cation against retrogradation up to pH 6.20 while DTPA acts up to 9.00. Therefore, the cause of poorer nutrition of plants fertilized with Fe 13 Top could be a result of partial iron retrogradation. In the case of Fe 9 Premium and Librel Fe DP7 fertilizers bound by DTPA, the state of plant nutrition was better and similar for both fertilizers.

Other authors, who examined chelates supplied to rockwool medium (CHOHURA et al. 2006), proved that the highest mean iron content in index parts was found in plants whose iron source was Librel Fe DP7 (135.2 mg $Fe \cdot kg^{-1}$ d.m.), while after application of Top 12 the analogous content was 123.1 mg $Fe \cdot kg^{-1}$ d.m.

Taking into account the average data for the whole growing period, Fe fertilization of greenhouse tomato up to the level of 50 $Fe \cdot dm^{-3}$ of peat contributed to the improvement of plant nutritional state in relation to the control treatment, not fertilized with iron, containing on average 17.9 mg $Fe \cdot dm^{-3}$. The increase in Fe concentration to 75 $Fe \cdot dm^{-3}$ resulted in the best state of plant nutrition while the content of 100 $Fe \cdot dm^{-3}$ caused some reduction in Fe uptake by tomato plants (Figure 2). That could have been due to the fact that some legands, especially EDTA, can produce disadvantageous effects (LOPEZ et al. 2007). In our own investigation, there were no symptoms of phytotoxicity or any visible disturbances in the growth and development of greenhouse tomato, despite the fact that relatively high doses of chelate fertilizers had been applied.

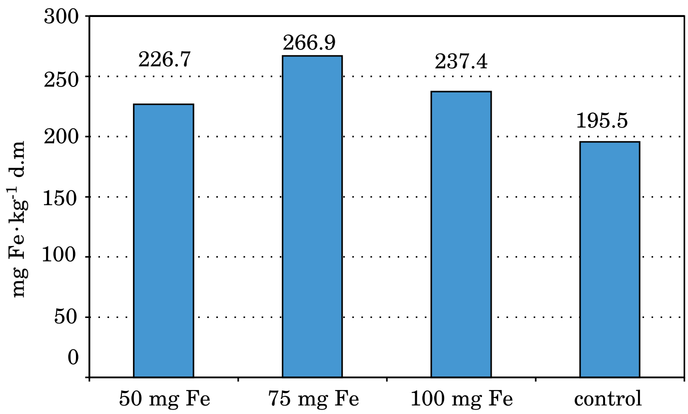

Fig. 2. Effect of iron concentration in peat substrate on Fe content in index part of greenhouse tomato (mean for 2006-2007, mg $Fe \cdot kg^{-1}$ d.m.)

CONCLUSIONS

1. The highest content of iron in tomato leaves was determined when chelate Fe 9 Premium (DTPA) was used, which points to the fact that it was the best source of Fe for this plant species.

2. The highest mean Fe content for all the terms of analyses appeared in the leaves of plants cultivated with 75 mg $Fe \cdot dm^{-3}$ in the growing medium. Further increase in the Fe content up to 100 mg $Fe \cdot dm^{-3}$ resulted in a decrease in the iron content in plant index parts.

3. In June, after the beginning of yielding, a considerable decrease in the Fe content in plant index parts occurred in comparison to the period before fruit maturation as well as the end of yielding.

4. There were no symptoms of phytotoxicity or visible disorders regarding tomato growth and development caused the examined Fe chelates supplied in the doses of 32.1, 571 and 82.1 mg $Fe \cdot dm^{-3}$ of the substrate whose initial Fe concentration after peat liming was on average 17.9 mg $Fe \cdot dm^{-3}$.

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