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The effect of the kind of Fe chelate on yielding and quality of greenhouse tomato fruits

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ABSTRACT

A two-year-greenhouse experiment was designed to investigate 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 yield and fruit quality of the 'Merkury' F_1 greenhouse tomato cultivar grown in peat substrate. Each of the tested fertilisers was applied in three different doses in order to reach the level of 50, 75 or 100 mg available Fe per 1 dm^3 of growing medium. In the control treatment the amount of this nutrient was equal to 17.9 mg dm^{-3}. The tomato was cultivated from transplants on benches in the period from the beginning of April to the end of July.

The highest marketable yield of tomato fruits was obtained from plants fertilised with Fe 9 Premium (DTPA), while the lowest was from the treatment with Fe 13 Top (EDTA) chelate. Both of these sources of iron were equally efficient for the early crop yield, which was significantly higher than that of other tested fertilisers. Irrespective of the Fe source, the most favourable dose of this nutrient for marketable and early fruit yield was 50 mg Fe dm^{-3}. Both tested factors had little effect on fruit composition. The only exception was a significant drop of vitamin C content in the treatment supplied with Fe 9 Premium and an increment of Na in the case of Fe 13 Top use. The increase of Fe in the growing medium up to 75 and 100 mg dm^{-3} adversely affected the amount of P in tomato fruits.

Key words: early yield, fruit composition, iron fertilisation, marketable yield

INTRODUCTION

Iron ions play a number of important functions in plants due to their possibility of changing Fe^{+3}/Fe^{+2} valence (Guerinot and Yi 1994). Even a temporary deficiency of this microelement causes a considerable reduction in plant growth and yielding (Fernandez and Ebert 2005). According to Mills and Jones (1997), the recommended iron content for vegetables in their growing medium ranges widely, from 5 to 100 mg Fe dm^{-3}. The greenhouse tomato is classified in the group of vegetables featuring high nutrition needs as far as iron is concerned (Chohura et al. 2007). The characteristic symptoms of iron deficiency in tomatoes are chlorosis, which usually appears at the base of leaflets on the youngest leaves (Bergman 1992). The problems connected with providing this species with appropriate amounts of iron do not usually result from the lack of iron in a growing medium, but from the transformation of Fe ions into a form not available to plants or disadvantageous conditions regarding root system functioning.

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VERSITA

The chemical sorption of iron consists of forming colloid ferric hydroxide (Tiffin et al. 1960), which mainly takes place in traditionally cultivated plant with ferric sulphate as a common use source of iron. Chlorosis caused by iron deficiency is most often connected with high pH, iron retrogradation with phosphates and carbonates, lack of oxygen in the rhizosphere, or iron antagonism under the influence of a high concentration of manganese, zinc or copper (Fernandez and Ebert 2005). Therefore, iron chelates have become increasingly popular in plant fertilisation. A characteristic property of chelate compounds is forming lined bonds with metal cations. The latter feature good water solubility, a low dissociation constant value and high durability. In this way, iron ions are protected from retrogradation and remain available for plants. As Schmidt and Steinbach (2000) reported, the durability of such a complex and iron availability for the plant mainly depends on the kind of chelate ligand. In fertilisation the following kinds of ligands are often applied: EDTA (ethylenediaminetetraacetic acid), DTPA (diethylenetriaminepentaacetic acid) or HEEDTA (hydroxyl-2-ethylenediaminetriacetic acid) (Stuart et al. 1991, Alvarez-Fernandez at al. 2005); the study investigated the effect of the kind of a carrier and iron concentration on the yielding and fruit quality of greenhouse tomato grown in a peat substrate.

MATERIAL AND METHODS

The experiments were conducted in a heated greenhouse. Greenhouse tomatoes of the 'Merkury' F_1 cultivar were planted into a 15 cm layer of peat substrate on benches, with 50 dm^3 substrate volume per plant. The transplants were planted in a spacing of 0.65 × 0.5 m, in a density of three plants per 1 m^2 of bench. The tomatoes were cultivated from the second 10-days of April to the third 10-days of July and trained for one stem and five trusses. The air temperature was maintained at a level of 20-25°C during the day and 16-18°C at night. The air humidity was kept between 60-70% while the growing medium moisture was within 60-65% of the container water capacity at the seedling stage, 65-70% at flowering, and 70-75% at the fruit-developing stage. Peat substrate produced by Hartmann, which was limed with chalk to 5.50 pH, was used as a growing medium. The substrate content of nutrients before transplant plating was standardised to the following recommended values (Komosa 2005): N – 220, P – 180, K – 350, Ca – 2000, Mg – 200, Mn – 20, Zn – 20, Cu – 5.0, B – 1.5 and Mo – 1.5 (mg dm^{-3}). In the second 10-days of June, the tomatoes were supplementary fertilised using 5 g N and 10 g K per 1 m^2 of growing medium. The experiment was established in two factorial designs, with six plants cultivated on one plot. The first factor involved the chelates differing in percentage content of iron and the kind of ligand Fe bound into the complex: Fe 8 Forte (EDTA+HEEDTA), Fe 9 Premium (DTPA), Fe 13 Top (EDTA) and Librel Fe DP7 (DTPA). The second factor was iron content in the growing medium, which was established to reach the following levels: 50, 75 and 100 mg Fe dm^{-3}, while in the control treatment Fe values were 17.9 Fe dm^{-3} (after liming the peat). Harvest took place twice a week with grading into the following classes: fruit mean over 6 cm - grade IA, 4.5-6.0 cm - IB, 3.5-4.5 cm - grade II and below 3.5 cm were not classified. Marketable yield contained fruits of grades IA, IB and II, while the early yield consisted of tomatoes obtained during the first three harvests. The assessment of fruit nutritional value involved the determination of dry matter by drying it to a stable weight at 105°C and vitamin C assaying using the Tillman method. Tomato fruits were subjected to phosphorus and magnesium using the spectrophotometric method, as well as potassium, calcium and sodium using the flame photometric method after extraction in 2% acetic acid. Nitrate nitrogen was analysed using the potentiometric method. The obtained results were subjected to statistic evaluation on the basis of an analysis of variance for a two factorial design at a significance level of $p = 0.05$. Data of the iron content in tomato fruits are not included in the paper because the amounts of this nutrient remained below the detection level of our laboratory equipment. On average, the content of Fe in the edible portion of fully matured fruits may reach the level of 0.3-0.5 mg per 100 g of fresh weight (Lorenz and Maynard 1988).

RESULTS AND DISCUSSION

The effect of the examined factors was similar for both years of the experiment (2006-2007) and, therefore, the mean values for the entire period under investigation were presented. On the basis of the data shown in Table 1, it may be possible to state that the most beneficial source of iron for greenhouse tomato cultivated in peat substrate was Fe 9 Premium (DTPA) chelate, which resulted in the highest marketable as well as early fruit yield. The average marketable yield for the plants fertilised with the mentioned chelate was significantly higher

Table 1. Marketable and early yield of 'Merkury' F_1 greenhouse tomato fruits in relation to the kind of chelates and iron content inpeat substrate (kg m^{-2})

	Kind of Fe fertiliser	Fe content in peat substrate (mg dm^{-3})			
		50	75	100	Mean
Marketable yield	Fe 13 Top (EDTA)	14.64	13.33	13.35	13.77
	Fe 8 Forte (EDTA+HEEDTA)	14.50	14.52	14.28	14.43
	Librel Fe DP7 (DTPA)	14.59	14.84	13.14	14.19
	Fe 9 Premium (DTPA)	14.17	14.53	15.41	14.70
	Mean	14.48	14.30	14.04	14.27
	Control				14.02
	$LSD_{p=0.05}$ for: fertiliser - 0.31, dose - 0.28, interaction - 0.41				
Early yield	Fe 13 Top (EDTA)	3.50	3.67	3.76	3.64
	Fe 8 Forte (EDTA+HEEDTA)	3.57	3.12	3.09	3.26
	Librel Fe DP7 (DTPA)	3.65	3.31	3.24	3.40
	Fe 9 Premium (DTPA)	3.31	3.57	4.14	3.67
	Mean	3.51	3.42	3.56	3.50
	Control				3.13
	$LSD_{p=0.05}$ for: fertiliser - 0.12, dose - n.s., interaction - 0.17				

than the ones obtained with the use of the remaining fertilisers, except for the treatment with Fe 8 Forte as a source of iron. The last one, a blended chelate, is reported equally highly effective at both high and low pH values (Bergman 1992). A significantly lower average marketable yield was recorded after the application of Fe 13 Top chelate, which was even slightly lower than in the control treatment. This finding is not in agreement with the data reported by Gul and Sevgican 1989, and Komosa et al. (2001), who did not find any considerable differences in the yielding of greenhouse tomato grown in rockwool when different chelates were introduced. The diversified yielding recorded in our own investigation, especially in treatments with EDTA chelate as the iron source, could result from a poor availability of iron as the ligand, as it features a high stability only up to pH 6.20 (Sanchez et al. 2005), while at higher pH values the phenomenon of increased iron retrogradation becomes a fact. During the course of the experiment, the substrate of initial 5.50 pH showed a gradual increase in pH, up to 6.50-6.80 at the end of the growing period, as a result of plant watering with slightly alkaline water.

Fe fertilisation up to 50 mg Fe dm^{-3} in peat substrate contributed to the increase in average marketable fruit yield in comparison to the control treatment, which contained an average of 17.9 mg Fe dm^{-3}. Increased iron concentration, up to 75 and 100 mg Fe dm^{-3}, did not bring any further increase in average fruit yield. The only exception was the application of Fe 9 Premium which, at higher contents of this element in the growing medium (up to 75 and 100 mg Fe dm^{-3}), resulted in a systematic and significant increase of marketable fruit yield. The poor efficiency of high Fe doses in yield increment of vegetables has been observed in some other studies. The research conducted by Kozik at al. (2011) indicated that different sources of Fe did not affect the crop yield of lettuce if applied at rates within 45-220 mg Fe dm^{-3}, while Librel Fe (DTPA) even caused some reduction of yield. Loop (1983) found that 50 ppm of iron is needed for maximum biomass yield of such agriculture crops as rape and maize, and 40 ppm for oats.

The highest recorded value regarding average marketable fruit yield, amounting to 15.41 kg m^{-2}, was obtained at 100 mg Fe dm^{-3} in the growing medium after the afore mentioned chelate application. Introducing Fe 8 Forte and Librel Fe DP7 fertilisers, the highest yields were achieved at 75 mg Fe dm^{-3} of peat. In the case of Fe 13 Top chelate, the most satisfactory yielding was recorded at 50 Fe dm^{-3}, yet the increase in Fe concentration up to 75 and 100 mg Fe dm^{-3} of peat did have an effect in the significant decrease in yielding. Chohura et al. (2006) reported similar results for a comparatively long growing period.

Differentiated Fe fertilisation also influenced the earliness of tomato yielding; however, it was not dependent on Fe content in the growing medium but only on the kind of fertiliser applied. A significantly higher early yield was obtained when

Table 2. 'Merkury' F_1 greenhouse tomato fruit composition in relation to the kind of chelate and iron content in peat substrate

	Kind of Fe fertiliser	Fe content in peat substrate (mg dm^{-3})			
		50	75	100	Mean
Dry mater (%)	Fe 13 Top (EDTA)	4.88	4.77	4.74	4.80
	Fe 8 Forte (EDTA+HEEDTA)	4.75	5.03	5.04	4.94
	Librel Fe DP7 (DTPA)	4.80	5.15	4.81	4.92
	Fe 9 Premium (DTPA)	4.78	4.70	4.64	4.71
	Mean	4.80	4.91	4.81	4.84
	Control				5.01
	$LSD_{p = 0.05}$ for: fertiliser - 0.31, dose - 0.28, interaction - 0.41				
Vitamin C (mg 100 g^{-1}f.m.)	Fe 13 Top (EDTA)	17.92	16.47	16.20	16.86
	Fe 8 Forte (EDTA+HEEDTA)	17.47	16.15	14.15	15.92
	Librel Fe DP7 (DTPA)	16.05	15.02	17.15	16.07
	Fe 9 Premium (DTPA)	16.15	12.71	13.55	14.14
	Mean	16.90	15.09	15.26	15.75
	Control				16.10
	$LSD_{p = 0.05}$ for: fertiliser - 0.12, dose - n.s., interaction - 0.17				
Sodium (mg Na100 g^{-1}f.m.)	Fe 13 Top (EDTA)	1.31	1.63	1.95	1.63
	Fe 8 Forte (EDTA+HEEDTA)	1.06	1.35	1.39	1.27
	Librel Fe DP7 (DTPA)	0.99	1.25	1.02	1.09
	Fe 9 Premium (DTPA)	1.12	1.00	1.12	1.08
	Mean	1.12	1.31	1.37	1.27
	Control				0.84
	$LSD_{p=0.05}$ for: fertiliser - 0.21, dose - n.s., interaction - n.s.				
Nitrates (mg NO_3 kg^{-1}f.m.)	Fe 13 Top (EDTA)	34.2	41.8	35.4	37.1
	Fe 8 Forte (EDTA+HEEDTA)	27.6	26.3	41.2	31.7
	Librel Fe DP7 (DTPA)	29.3	22.7	35.6	29.2
	Fe 9 Premium (DTPA)	34.2	28.6	31.1	31.3
	Mean	31.3	29.9	35.8	32.3
	Control				31.3
	$LSD_{p = 0.05}$ for: fertiliser – n.s., dose - n.s., interaction - n.s.				

Fe 9 Premium and Fe 13 Top were used. Contrary to the treatment fertilised with Fe 8 Forte and Librel Fe DP7 chelates, the increase in Fe content in the growing medium with the use of Fe 13 Top and Fe 9 Premium contributed to a significant increase of the size of the average early yield. However, tomato fruits from the plants fertilised with Fe 13 Top and Fe 9 Premium contained less dry matter than the other ones. The highest content of dry matter – 5.10% – was recorded for fruits from the control treatment. Increased Fe content in the growing medium affected dry matter content (4.80-4.91%) to a slight degree on average, contributing to an insignificant decrease in average vitamin C content in fruits. The highest average vitamin C values were found in tomato fruits from plants fertilised with Fe 13 Top chelate. The values obtained in our own investigation, regarding the amounts of dry matter and vitamin C, were typical for greenhouse tomatoes (Halmann and Kobryń 2002).

The mineral composition of tomato fruits expressed by the content of phosphorus, potassium, magnesium and sodium was generally not affected by the form and rate of Fe chelate fertilisers (Tabs 2-3). The only exception was the increment of Na content in treatments supplied with Fe 13 Top (EDTA) fertiliser, regardless of the dose of this nutrient. This effect is easy to explain by the contamination of EDTA chelates by sodium and the absence of this element in the other bonding ligands. Phosphorus content was significantly reduced by heavy Fe fertilisation at the rates of 75 and 100 mg

Table 3. Mineral element content in 'Merkury' F_1 greenhouse tomato fruits in relation to the kind of chelate and iron concentration in peat substrate (mg 100 g^{-1} f.m.)

	Kind of Fe fertiliser	Fe content in peat substrate (mg dm^{-3})			
		50	75	100	Mean
Phosphorus	Fe 13 Top (EDTA)	22.5	19.1	18.6	20.1
	Fe 8 Forte (EDTA+HEEDTA)	22.1	20.4	17.3	19.9
	Librel Fe DP7 (DTPA)	23.1	21.0	21.0	21.7
	Fe 9 Premium (DTPA)	19.9	17.6	17.6	18.4
	Mean	21.7	19.8	18.9	20.1
	Control				21.9
	$LSD_{p = 0.05}$ for: fertiliser - n.s., dose – 0.9, interaction - n.s.				
Potassium	Fe 13 Top (EDTA)	207	215	225	216
	Fe 8 Forte (EDTA+HEEDTA)	226	201	207	211
	Librel Fe DP7 (DTPA)	228	233	227	229
	Fe 9 Premium (DTPA)	203	198	186	196
	Mean	216	212	211	213
	Control				210
	$LSD_{p = 0.05}$ for: fertiliser – n.s., dose - n.s., interaction - n.s.				
Magnesium	Fe 13 Top (EDTA)	16.84	15.74	15.88	16.15
	Fe 8 Forte (EDTA+HEEDTA)	16.63	16.10	15.88	16.20
	Librel Fe DP7 (DTPA)	16.56	17.25	17.56	17.12
	Fe 9 Premium (DTPA)	15.30	15.28	14.15	14.91
	Mean	16.33	16.09	15.87	16.10
	Control				16.51
	$LSD_{p = 0.05}$ for: fertiliser - n.s., dose – n.s., interaction - n.s.				
Calcium	Fe 13 Top (EDTA)	12.20	10.73	10.48	11.14
	Fe 8 Forte (EDTA+HEEDTA)	11.88	11.32	12.50	11.90
	Librel Fe DP7 (DTPA)	10.85	11.54	11.06	11.15
	Fe 9 Premium (DTPA)	10.56	10.72	10.49	10.59
	Mean	11.37	11.08	11.13	11.19
	Control				10.01
	$LSD_{p = 0.05}$ for: fertiliser – n.s., dose - n.s., interaction - n.s.				

Fe dm^{-3}. In the literature, the depression effect of high phosphorus (in addition to high pH) on iron uptake and utilisation by plants has been reported (Bergman 1992). However, no indication could be found about an adverse effect of iron fertilisation on P uptake. The accumulation of nitrates in tomato fruits was very low – within 22.7-41.8 mg per 1 kg fresh weight – and not significantly influenced by the iron nutrition.

CONCLUSIONS

1. The kind of Fe chelate applied significantly affected the marketable yield of the 'Merkury' F_1 greenhouse tomato cultivar grown in peat substrate. The highest yield was produced by the plants fertilised with Fe 9 Premium, while the lowest one was recorded for Fe 13 Top chelate.
2. Increased Fe content in the growing medium, from 50 to 75 and 100 mg Fe dm^{-3}, did not influence the greenhouse tomato marketable yield, except for the treatment where Fe 9 Premium was used, of which a level of 100 mg Fe dm^{-3} proved to be the most advantageous for plants.
3. Out of all of the fertilisers introduced to the peat substrate, the highest early yield resulted from Fe 9 Premium and Fe 13 Top chelate application.
4. The factors investigated in the experiment had a negligible effect on tomato fruit composition. The only exception was the increment of Na content in treatments supplied with Fe 13 Top

(EDTA) fertiliser, regardless of the dose of this nutrient.

REFERENCES

Álvarez-Fernández A., Garc´ia-Marco S., Lucena J., 2005. Evaluation of synthetic iron(III)-chelates (EDDHA/Fe3+, EDDHMA/Fe3+ and the novel EDDHSA/Fe3+) to correct iron chlorosis. Europ. J. Agronomy 22: 119-130.

Bergmann W., 1992. Nutritional disorders of plants. Development visual and analytical diagnosis. Gustav Fisher. Verlag. Jena, Stuttgart, New York.

Chohura P., Kołota E., Kołota E., 2006: Wpływ chelatów żelazowych Librel Fe-DP7, Pionier Fe 13 i Top 12 na stan odżywienia mikroelementami pomidora szklarniowego w wełnie mineralnej. Acta Agrophysica 7(3): 549-560.

Chohura P., Kołota E., Komosa A., 2007. The effect of different source of iron on nutritional value of greenhouse tomato fruit grown in peat substrate. Veg. Crops Res. Bull. 67: 55-61.

Fernández V., Ebert G., 2005. Foliar iron fertilization: A critical review. J. Plant Nutr. 28: 2113-2124.

Guerinot M.L., Yi Y., 1994. Iron, nutritious, noxious, and not readily available. Plant Physiol. 104: 815-820.

Gul A., Sevgican A., 1989. Effect of growing media on glasshouse tomato yield and quality. Acta Hort. 303: 145-150.

Halmann H., Kobryń J., 2002. Fruit quality estimation of two tomato types (*Lycopersicon esculentum* Mill. and *Lycopersicon esculentum* var. *cerasiforme*) grown on rockwool in the glasshouse. Folia Hort. 14(1): 79-86.

Komosa A., Kołota E., Chohura P., 2001. Usefulness of iron chelates for fertilization of greenhouse tomato cultivated in rockwool. Veg. Crops Res. Bull. 55: 35-40.

Komosa A., 2005. Aktualne tendencje w żywieniu roślin warzywnych uprawianych pod osłonami. Zesz. Nauk. AR we Wrocławiu 515: 267-279.

Kozik E., Tyksiński W., Bosiacki M., 2011. A comparison of the efficiency of organic and mineral iron compounds in the greenhouse cultivation of lettuce. J. Elementol. 16(1): 59-68.

Laurie S.H., Tancock N.P., Mcgrath S.P., Sanders J.R., 1991. Influence of complexation on the uptake by plants of iron, manganese, copper and zinc: II. Effect of DTPA in a multi-metal and computer simulation study. J. Exp. Bot., 42: 515-519.

Loop P.L., 1983. Untersuchungenzur Diagnose des Eisen-Versorgungsgrades von Kulturpflanzen. Diss. Agrarw. Fak. Christian-Albert-Univ. Kiel 1983.

Lorenz O.A., Maynard D., 1988. Knott's handbook for vegetable growers. 3rd ed. Wiley, New York.

Mills H.A., Jones Jr. J., 1996. Plant Analysis Handbook II, MicroMacro Publishing Inc, Athens, GA, USA.

Sánchez A.S., Juárez M., Sánchez-Andreu J., Jordá J., Bermúdez D., 2005. Use of humic substances and amino acids to enhance iron availability for tomato plants from applications of the chelate FeEDDHA. J. Plant Nutr. 28: 1877-1886.

Schmidt W., Steinbach S., 2000. Sensing iron – a whole plant approach. Ann. Bot. 86: 589-593.

Tiffin L.O., Brown J.C., Holmes R.S., 1960. Chelating agent and plant nutrient interactions affecting the iron nutrition of soybeans. Soil Sci. Soc. Am. J. 24: 120-123.

WPŁYW RODZAJU CHELATU Fe NA PLONOWANIE I JAKOŚĆ OWOCÓW POMIDORA SZKLARNIOWEGO

Streszczenie: W 2-letnim doświadczeniu badano wpływ czterech nawozów chelatowych, 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 plonowanie i jakość owoców pomidora szklarniowego odmiany 'Merkury F_1' uprawianego w substracie torfowym. Każdy z badanych nawozów był stosowany w takiej ilości, aby osiągnąć zasobność podłoża w żelazo wynoszącą: 50, 75 i 100 mg Fe dm^{-3}. Średnia zawartość tego składnika w kontroli wynosiła 17,9 mg Fe dm^{-3}. Pomidory uprawiano od kwietnia do lipca z rozsady sadzonej na stołach. Najwyższy plon handlowy owoców pomidora uzyskano z roślin nawożonych nawozem Fe 9 Premium (DTPA), a najniższy po zastosowaniu chelatu Top 13 (EDTA). Obydwa te nawozy jako źródła żelaza dla roślin miały taki sam wpływ na wysokość plonu wczesnego pomidora, który był istotnie wyższy po ich zastosowaniu w porównaniu do pozostałych testowanych chelatów. Najlepsze efekty produkcyjne w plenności i wczesności plonowania uzyskano przy zasobności podłoża wynoszącej 50 mg Fe dm^{-3}. Rodzaj nawozu chelatowego i dawka żelaza miały niewielki wpływ na skład chemiczny owoców. Wyjątkiem były zawartość witaminy C, która uległa istotnemu obniżeniu po zastosowaniu Fe 9 Premium oraz wzrost koncentracji sodu po zastosowaniu Fe 13 Top. Zwiększenie zawartości żelaza w podłożu do 75 i 100 mg Fe dm^{-3} ograniczało istotnie zawartość fosforu w owocach.

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