J. Elem. s. 1065–1072
DOI: 10.5601/jelem.2014.19.3.486

THE EFFECT OF TYTANIT APPLICATION ON THE CONTENT OF SELECTED MICROELEMENTS AND THE BIOLOGICAL VALUE OF TOMATO FRUITS

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Abstract

Titanium is an element exhibiting bio-stimulatory properties. The aim of the following investigations was to assess the effect of Tytanit application on the content of micronutrients in leaves and fruits, as well as the biological value of fruits from tomatoes grown in rockwool. The following levels of titanium side dressing were used: the control (no titanium applied), Ti-I (corresponding to the annual dose of 80 g Ti ha^{-1}), Ti-II (240 g Ti ha^{-1}), Ti-III (480 g Ti ha^{-1}) and Ti -IV (960 g Ti ha^{-1}). Tytanit at the level Ti-I had significant impact on the iron and manganese content in indicator parts of plants. A significant effect of Ti application on the zinc content in indicator parts of plants was observed at the Ti-II treatment in comparison with the control and other treatments. The application of Ti did not have any significant effect on the Cu content in indicator parts, except for the Ti-IV treatment. Increasing Ti doses caused a significant reduction of the copper content in fruits except for Ti-II and Ti-III. The application of Ti was shown to influence total acidity of tomato fruits. The highest content of nitrates was recorded in the combination Ti-III (30.03 mg kg^{-1}). No effect of Ti on the nitrate content was observed in the other combinations. A significant increase was found for the lycopene content in fruits when applying Ti-I (46.11 mg kg^{-1}) in relation to the other doses.

Key words: titanium, nitrates, lycopene, index parts, fruits.

WPŁYW STOSOWANIA TYTANITU NA ZAWARTOŚĆ WYBRANYCH MIKROLELMENTÓW I WARTOŚĆ BIOLOGICZNĄ OWOCÓW POMIDORA

Abstrakt

Tytan jest pierwiastkiem o właściwościach biostymulujących. Celem badań była ocena wpływu stosowania Tytanitu na zawartość mikroskładników w liściach i owocach oraz wartość

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biologiczną owoców pomidora uprawianego w wełnie mineralnej. Badano następujące poziomy dokorzeniowego stosowania tytanu wynoszące odpowiednio: kontrola (bez stosowania tytanu), Ti-I (co odpowiada dawce rocznej 80 g Ti ha^{-1}), Ti-II (240 g Ti ha^{-1}), Ti-III (480 g Ti ha^{-1}), Ti-IV (960 g Ti ha^{-1}). Wykazano istotny wpływ Tytanitu w dawce Ti-I na zawartości żelaza i manganu w częściach wskaźnikowych roślin. Stwierdzono istotny wpływ Ti na zawartość cynku w częściach wskaźnikowych roślin w kombinacji Ti-II w porównaniu z kontrolą i innymi kombinacjami. Stosowanie Ti nie miało istotnego wpływu na zawartość Cu w częściach wskaźnikowych z wyjątkiem kombinacji Ti-IV. Wzrastające dawki Ti miały istotny wpływ na zmniejszenie zawartości miedzi w owocach z wyjątkiem kombinacji Ti-II i Ti-III. Wykazano wpływ Ti na kwasowość ogólną owoców pomidora. Największą zawartość azotanów stwierdzono w kombinacji Ti-III (30,03 mg kg^{-1}). Nie stwierdzono wpływu Ti na zawartość azotanów w pozostałych kombinacjach. Wykazano istotny wzrost zawartości likopenu w owocach w przypadku dawki Ti-I (46,11 mg kg^{-1}) w stosunku do innych kombinacji.

Słowa kluczowe: tytan, azotany, likopen, części wskaźnikowe, owoce.

INTRODUCTION

Titanium is an element exhibiting bio-stimulatory properties (MICHALSKI 2008). Its effect consists, for example, in the stimulation of activity of certain enzymes, such as lipogenases (DAOOD 1998). One of the commercially available fertilizers containing titanium is Tytanit (0.8% Ti, i.e. 8.5 g Ti in the chelated form per 1 l stimulant). According to WÓJCIK and WÓJCIK (2001), Tytanit application has a positive effect on plant growth and development. The application of Tytanit showed an advantageous effect on the yielding of plants from the family of *Solanaceae* (JANAS et al. 2002). A positive effect of titanium application was also reported in the culture of orchard plants such as apples (WÓJCIK 2002). This element also reduces plant damage caused by heavy metals (LESKÓ et al. 2002).

The aim of the investigations was to assess the effect of Tytanit application on the content of selected micronutrients in tomato leaves and fruits as well as on the biological value of fruits in tomato grown in rockwool.

MATERIAL AND METHODS

Plant-growing experiments were conducted in 2010 - 2011. The effect of Tytanit fertigation on the content of microelements in leaves and fruits as well as on the biological values of fruits was investigated in tomato grown in rockwool. The experiments were run in a greenhouse dedicated to growing plant cultures, equipped with a modern climate control system. Climate parameters (temperature, CO_2 content, % RH) were recorded using the Synopta software. The greenhouse facilities comprised a modern, computer-controlled fertigation system and energy-conservation curtains. Plants were grown at a density of 2.7 plants m^{-2}. The following doses of titanium side dressing were tested, i.e. the control (no titanium applied), Ti-I (corresponding to an annual dose of 80 g Ti ha^{-1}), Ti-II (240 g Ti ha^{-1}), Ti-III (480 g Ti ha^{-1}) and Ti-IV (960 g Ti ha^{-1}). Seeds were sown to culture plugs in the 1st half of March each year. After 2 weeks, seedlings were transplanted to rockwool cubes (10x10x10 cm). Transplants were moved to permanent beds on 15 April (2010) and 19 April (2011). The experiment was concluded on the 30th of September each year of the study. The experiment was conducted on the ISI 68249 tomato variety. Plants were grown in standard rockwool (density of 60 kg m^{-3}, mats of 100x15x7.5 cm). A one-factor experiment was established in a completely randomized system, with six replications, two plants in each. Biological plant protection was used. All cultivation measures were performed in accordance with the current recommendations for tomato growing (Adamicki et al. 2005). Plant fertigation was applied using a standard nutrient solution containing (in mg dm^{-3}): N-NH_4 – 2.0, N-NO_3 – 225, P-PO_4 – 50, K – 445, Ca – 150, Mg – 60, S-SO_4 – 115, Fe – 4.7, Mn – 0.3, Zn – 1.648, B – 0.40, Cu – 0.05, Mo – 0.08, at pH 5.50 and EC 3.00 mS cm^{-1}. Tytanit fertilizer (by Intermag Olkusz), containing 8.5 g Ti in 1 dm^3, was the source of titanium. The nutrient solution dose depended on the development phase of the plants and climatic conditions. In the period of intensive plant yielding and high temperatures (the months of June-July), 3.0-3.5 dm^3 nutrient solution per plant was applied daily, in 15-20 single doses at 20-30% drip from mats.

Leaf samples for chemical analyses were collected on 15 June, 15 July and 16 August each year of the study. Indicator parts comprised 8th-9th leaves counting from the plant apex. One bulk sample consisted of 12 leaves collected from plants within a given combination. Representative fruit samples were collected in the 2nd half of August each year of the study. The collected plant material was dried at 45-50°C and ground. In order to determine the total content of iron, manganese, zinc and copper, the plant material was mineralized in the mixture of acetic and perchloric acids (3:1 v/v). After mineralization Fe, Mn, Zn and Cu were determined according to ASA. Biological parameters of fruits were determined using the following methods: nitrates by colorimetry, lycopene by HPLC, total acid by PN-90 A 75101/04. Results of chemical analyses were analyzed statistically using the Duncan test with inference at α=0.05.

RESULTS AND DISCUSSION

Micronutrient content in leaves

A significant effect of Ti application on changes in the content of metallic microelements was observed in indicator parts of plants (Table 1). The highest content of iron and manganese was determined at Ti-I in comparison to the control as well as Ti-II – Ti-IV. According to Malinowska and Kalembasa (2012), titanium has a significant effect on the reduction of bioaccumulation of iron and manganese. Irrespective of a titanium level in this study, a higher mean content of iron in leaves was recorded than reported by Chohura and Komosa (2003), Komosa et al. (2011) and Kleiber et al. (2012). The detected manganese content was also higher than recorded by Kleiber et al. (2012), but lower than given by Chohura and Komosa (2003) and Komosa et al. (2011). Significantly the highest zinc content was recorded at the application of Ti-II (59.1 mg Zn kg^{-1} d.m.). The significantly lowest copper content (13.3 mg Cu kg^{-1} d.m.) was found at Ti-IV, with a simultaneous lack of impact at Ti-I – Ti-III. The reported copper content in leaves was lower than recorded by Komosa et al. (2011) and Kleiber et al. (2012), but higher than given by Chohura and Komosa (2003). The content of iron, manganese, copper and zinc found in this study (except for Ti-I) in indicator parts fell within the ranges optimal for tomato (Campbel 2000).

Table 1

The effect of Tytanit on the mean content (mg kg^{-1} d.m.) of metallic microelements in tomato leaves (means from 2010-2011)

Treatment	Fe	Mn	Zn	Cu
Control	168.4*ab*	198.1*a*	39.70*c*	16.20*b*
Ti-I	175.4*b*	241.9*b*	14.90*a*	15.10*b*
Ti-II	163.6*a*	199.1*a*	59.10*d*	16.20*b*
Ti-III	149.6*a*	198.8*a*	24.80*b*	15.40*b*
Ti-IV	149.8*a*	181.3*a*	30.30*b*	13.30*a*

Values designated same letters do not differ significantly at α=0.05.

Microelement content in fruits

A multifaceted effect was caused by Ti application in the nutrient solution applied in fertigation on the content of iron and zinc in tomato fruits (Table 2). The significantly higher content of iron and zinc was detected in the combination of Ti-IV (respectively 72.0 mg Fe kg^{-1} d.m., 19.8 mg Zn kg^{-1} d.m.) than in the Ti-II treatment (70.0 mg Fe kg^{-1} d.m., 19.5 mg Zn kg^{-1} d.m.). The lowest content of iron and zinc was found in the combination Ti-I (57.4 mg Fe kg^{-1} d.m. and 13.5 mg Zn kg^{-1} d.m.). The iron content detected herein in tomato fruits was lower than recorded by Chohura et al. (2009) and Kleiber et al. (2012), but higher than demonstrated by Komosa et al. (2011) and Jarosz et al. (2012). The application of increasing Tytanit doses in the nutrient solution had no effect on the manganese content in tomato fruits, which ranged from 12.8 mg Mn kg^{-1} d.m. (Ti-IV) to 14.9 mg Mn kg^{-1} d.m. (Ti-I). The content of manganese recorded in this study in tomato fruits was higher than given by Kleiber et al. (2012), but lower than reported by Komosa et al. (2011) or Jarosz et al. (2012). A significant effect of titanium fertigation on reducing the copper content in tomato fruits was found for combinations Ti-I

(13.2 mg Cu kg^{-1} d.m.) – Ti-IV (4.0 mg Cu kg^{-1} d.m.). The copper content determined in the control as well as combinations Ti-II – Ti-IV was lower than the levels given by Komosa et al. (2011) or Kleiber et al. (2012). The copper content in tomato fruits was higher (except for combination Ti-IV) than the one reported by Jarosz et al. (2012).

Table 2

The effect of Tytanit on the mean content (mg kg^{-1} d.m.) of metallic microelements in tomato fruits (means from 2010-2011)

Treatment	Fe	Mn	Zn	Cu
Control	65.50*b*	13.60*a*	14.60*a*	7.800*b*
Ti-I	57.40*a*	14.90*a*	13.50*a*	13.20*c*
Ti-II	70.00*c*	14.30*a*	19.50*b*	8.600*b*
Ti-III	64.40*b*	14.10*a*	15.60*a*	7.900*b*
Ti-IV	72.00*c*	12.80*a*	19.80*b*	4.000*a*

Values designated the same letters do not differ significantly at α=0.05.

Biological parameters of fruits

Analyses showed the impact of Tytanit application on the total acidity of tomato fruits (Table 3). The highest content of citric acid was recorded in combination Ti-IV (0.33%), while the lowest one was in combination Ti-I (0.22%). No significant differences were found in the total acidity between the control (0.27%) and combinations Ti-II (0.26%) and Ti-III (0.28%). The detected acidity was lower than observed in studies by Hallmann and Rembiałowska (2007) and Majkowska-Gadomska et al. (2008). The highest nitrate content was observed in combination Ti-III (30.03 mg kg^{-1}). No effect of Tytanit on the nitrate content was found in the control combinations Ti-I and Ti-II as well as Ti-IV. The nitrate content found in fruits in this study was greater than the levels reported by Komosa et al. (2011); at the same time, it was lower than recorded in a field culture by Majkowska-Gadomska et al. (2009) and Gajc-Wolska et al. (2010).

Tomato fruits are an important source of antioxidants (Crozier et al. 1997, Fanasca et al. 2006). Lycopene, a carotenoid, is the primary pigment responsible for the red colour of fruits (Davis et al. 2003). Major sources of lycopene in the human diet are fruits of tomato, red peppers and red grapefruits (Hakala, Heinonen 1994). In the present study, a significant increase was recorded in the lycopene content in fruits when applying Ti-I (46.11 mg kg^{-1}) in relation to the control and treatments Ti-II – Ti-III. The application of the highest titanium concentration (Ti-IV) significantly reduced the lycopene content in fruits. In this study, we found a higher lycopene content than recorded by Hallmann and Rembiałowska (2007), although it was lower than the data given by Brandt et al. (2006) and Galpaz et al. (2008). According to Shi (2000), lycopene accounts for 80-90% of all carotenoids in ripe tomato fruits. The carotenoid content depends on the cultivar, environmental conditions and the ripeness of fruits (Shi 2000). Temperature is a factor influencing the lycopene content. Tomato fruits in the summer contain 30% less lycopene than those in a winter culture (Toor et al. 2006).

Table 3

The effect of Tytanit on selected biological parameters of tomato fruits (% means from 2010-2011)

Treatment	Total acid (% citric acid)	Nitrates (mg kg^{-1})	Lycopene (mg kg^{-1})
Control	0.270*b*	23.44*a*	34.26*b*
Ti-I	0.220*a*	26.10*a*	46.11*c*
Ti-II	0.260*b*	24.66*a*	34.30*b*
Ti-III	0.280*b*	30.03*b*	32.70*b*
Ti-IV	0.330*c*	24.35*a*	18.01*a*

Values designated the same letters do not differ significantly at α=0.05.

CONCLUSIONS

1. Tytanit application had a significant effect on the increase of the iron and manganese content in indicator parts (the highest Fe and Mn content at Ti-I) as well as zinc (the highest content at Ti-II).

2. No significant differences were found in the copper content in tomato leaves between the control and combinations Ti-I – Ti-III.

3. The multifaceted effect of titanium application was observed for the iron and zinc content in tomato fruits. For the copper content, a significant reduction was found at Ti-IV in comparison to the other combinations. The manganese content in fruits did not differ significantly.

4. A significant effect of Tytanit on the biological value of tomato fruits was observed in this study. The lycopene content was the highest in the case of Ti-I (46.11 mg kg^{-1}), whereas the Ti-IV treatment induced a significant increase in total acidity of fruits. The nitrate content did not differ significantly (except for Ti-III).

ACKNOWLEDGMENTS

The authors wish to thank the Intermag company from Olkusz for their assistance in conducting this experiment.

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