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APPLICATION OF "TYTANIT" IN GREENHOUSE TOMATO GROWING

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Abstract. Several studies conducted at present concern the application of biostimulants in intensive plant growing. Titanium is an element exhibiting characteristics of a biostimulant. The aim of the conducted analyses was to evaluate the effect of the application of titanium on plant nutrition, their yielding as well as contents of macronutrients and biological value of fruits in tomato grown on rockwool. The following levels of titanium were analysed: the control (no titanium applied), Ti-I (corresponding to an annual dose of 80 g $Ti \cdot ha^{-1}$), Ti-II (240 g $Ti \cdot ha^{-1}$), Ti-III (480 g $Ti \cdot ha^{-1}$) and Ti-IV (960 g $Ti \cdot ha^{-1}$). The source of titanium was "Tytanit" fertilizer (Intermag Olkusz). In the conducted study a significant effect of titanium application was found at the Ti-IV level on the produced total and marketable yields, at the simultaneous increase in the yield of fruits with the greatest diameters (classes I, II and III) in comparison to the other tested combinations. A significant effect of Ti was found on an increase in contents in the index parts of plants in case of nitrogen, phosphorus, calcium and magnesium (the greatest contents of N, P, Ca and Mg recorded at Ti-IV) as well as potassium (the highest content at Ti-I). A general trend was observed (except for Ti-II) for an increase in nitrogen content in fruits under the influence of titanium application, at a simultaneous lack of effect on contents of phosphorus and potassium. In case of calcium and magnesium the recorded changes were multifaceted. No significant effect of titanium was observed on contents of dry matter and sugars in fruits, as well as their active acidity. At the same time a significant variation of vitamin C contents in fruits was recorded, depending on the level of titanium nutrition of plants.

Key words: titanium, tomato, yielding, chemical composition, index parts, fruits

INTRODUCTION

Titanium is considered to be a biostimulant [Michalski 2008]. Biostimulants are biologically active substances, which may contain e.g. hormones, protein and microelements [Jankowski and Dubis 2008], and their role is to improve plant growth and devel-

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opment. The problem of plant nutrition with titanium is presented in more detail by Dumon and Ernst [1988]. Titanium had a beneficial effect on an increase in iron ion activity, enhanced pollen grain vigour and an increase in the rate of nutrient uptake, as well as an improved health condition of plants [Marschner 1995, Michalski 2008]. Many of the studies conducted to date showed a positive effect of titanium application, e.g. in the form of sprays, on plant growth and development. This thesis has been confirmed by studies conducted by Wójcik and Wójcik [2001]. Dobromilska [2007] conducted investigations using Tytanit, a fertiliser containing 0.8% Ti (m/m), i.e. 8.5 g Ti in 1 l stimulant and stated a positive effect of spraying of tomato plants with a titanium solution on their vegetation growth, at the simultaneous significant improvement of yielding and a limited formation of non-marketable fruits. Wójcik [2002] indicated a positive effect of spraying apple trees with titanium as a factor improving plant vigour at a limited uptake of Fe, Mn, Zn and Cu. In turn, Malinowska and Kalembasa [2012] indicated that titanium significantly influences bioaccumulation of metallic micronutrients (iron and manganese). A positive effect of titanium application was also shown in case of other fruit-bearing plants: plums, nectarines and peaches [Alcaraz-Lopez et al. 2003, Alcaraz-Lopez et al. 2004, Serrano et al. 2004]. Daood [1998] reported that titanium influenced positively lipoxygenase activity. In plants treated with titanium a higher content of chlorophyll and intensity of photosynthesis were observed [Grenda 2003]. Moreover, this nutrient limits plant damage caused by heavy metals [Leskó et al. 2002]. Titanium may have a significant effect on the quality of produced crops, e.g. increased contents of ascorbic acid or calcium in plants [Borkowski et al. 2006, Skupień and Oszmiański 2007a, 2007b, Martinez Sanchez et al. 1993].

Janas et al. [2002] showed a significant effect of Tytanit on yielding of aubergine, particularly under adverse climatic conditions. Marcinek and Hetman [2008] investigated the applicability of plant spraying with Tytanit in the culture of harlequin flower. Those authors stated that this measure may be recommended only in the years with adverse weather conditions, particularly a shortage of precipitation and excessively high temperatures in the spring after tuber planting. Moreover, the above mentioned authors showed that excessive Ti concentration has an adverse effect on the yield of offset bulbs. Skupień and Oszmiański [2007b] reported that the effect of strawberry spraying with titanium compounds on the content of antioxidants in their fruits is not clear.

The aim of the conducted investigations was to assess the effect of the application of titanium on plant nutrition, their yielding as well as macronutrient content and biological value of fruits in tomato culture on rockwool.

MATERIAL AND METHODS

The vegetation experiment was conducted in the years 2010–2011. Analyses were conducted on the effect of titanium fertigation on yielding and macronutrient content in leaves and fruits of tomato grown on rockwool. Vegetation experiments were run in a specialist culture greenhouse equipped with the modern climate control system. Climate parameters (temperature, CO_2 content, % RH) were recorded using the Synopta software. The facilities were equipped with a modern, computer-controlled fertigation system and energy-conservation curtains. Plants were grown at a density of 2.7 plants·m^{-2}.

The experiment was conducted on tomato cv. ISI 68249. Plants were grown in standard rockwool (density of 60 kg·m^{-3}, mats of 100 × 15 × 7.5 cm). Experiment was established in a completely randomized system, in six replications with two plants in each. Biological pest control was applied in that culture. All cultivation measures were performed in accordance with the current recommendations for tomato growing [Adamicki et al. 2005].

Seeds were sown to cultivation plugs in the 1st half of March in each year of the study. After 2 weeks seedlings were transplanted to rockwool cubes (10 × 10 × 10 cm). Plants were transplanted to permanent beds on 15 IV (2010) and 19 IV (2011). The experiment was concluded on 30 September in each year of the study. Plants were grown using fertigation in the closed system with no recirculation of the nutrient solution. A standard nutrient solution for tomato growing was used with the following nutrient contents (in mg·dm^{-3}): N-NH_4 2.0, N-NO_3 225.0, 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; pH 5.50 and EC 3.00 mS·cm^{-1}. The following titanium levels applied in nutrient solution were tested (in g Ti·ha^{-1}): the control, Ti-I (80), Ti-II (240), Ti-III (480) and Ti-IV (960) – what equal (mg Ti·plant·$year^{-1}$): 0; 2,01; 6,04; 12,08; 24,2. A fertiliser Tytanit (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 plants and climatic conditions. In the period of intensive plant yielding and high temperatures (months June – July) 3.0–3.5 dm^3 nutrient solution per plant were applied daily, in 15–20 single doses at 20–30% outflowing of drainage solution.

In the vegetation period the yield of fruits was recorded in terms of fruit quality grades: I – (diameter in w cm): over 10.2, II 10.2 – 8.2, III 8.2 – 6.7, IV 6.7 – 5.7, V 5.7 – 4.7 and VI less than 4.7. Marketable yield comprises fruits classified to grades I–V.

Leaf samples for chemical analyses were collected on 15.06, 15.07 and 16.08 in each of the years of the study. Index parts comprised 8–9 leaves counting from the top of the plant. One bulk sample was composed of 12 leaves collected from plants within a given combination. Representative samples of fruits were harvested in the 2nd half of August in each year of the study. Collected plant material was dried at a temperature of 45–50°C and then ground. In order to determine total nitrogen, phosphorus, potassium, calcium and magnesium contents plant material was mineralized in concentrated sulfuric acid. Nutrient contents were determined using the following methods: N-total – by the distillation method according to Kjeldahl in a Parnas–Wagner apparatus, P – by colorimetry with ammonium molybdate (according to Schillak), while K, Ca and Mg – by atomic absorption spectrometry (AAS). Selected parameters of biological value in fruits were determined, e.g. contents of dry matter by refractometry, total sugars using the Luff-Schoorl method, vitamin C – by the Tillmans method and pH by potentiometry.

Results of biometric measurements and laboratory analyses were analysed statistically using the Duncan test at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Yielding. In the conducted studies titanium application was shown to have a significant effect on total and marketable yields of plants (tab. 1). In case of total yield it was significantly highest at Ti-IV (19.19 kg·m^{-2}), while in the other combinations it did not differ significantly. In case of marketable yield it was shown to increase significantly at the application of the highest titanium concentrations (18.97 kg·m^{-2}, what equal 98.9% of total yield). In the worst combination (Ti-I) the percentage of marketable yield in relation to total yield was only 81.6%. Results of analyses are consistent with the data reported by Dobromilska [2007] for tomato and Janas et al. [2002] for aubergine at the foliar application of plants with a titanium solution.

Table 1. The influence of titanium on tomato yielding [in kg·m^{-2}]; (means from 2010–2011)

Ti level		I	II	III	IV	V	VI	Total yield	Marketable yield (I – V)
Yie-dling class	Control	0.13 b	1.44 b	4.46 b	7.33 a	3.33 c	1.24 b	17.93 a	16.69 b
	Ti-I	0.00 a	0.19 a	2.03 a	5.93 a	6.39 d	3.27 c	17.81 a	14.54 a
	Ti-II	0.40 c	1.42 b	4.36 b	6.06 a	2.52 b	1.96 b	16.72 a	14.76 a
	Ti-III	0.53 c	1.62 b	3.95 b	6.47 a	3.53 c	1.66 b	17.76 a	16.10 ab
	Ti-IV	1.31 d	2.33 c	7.13 c	7.08 a	1.12 a	0.22 a	19.19 b	18.97 c
% of total yield	Control	0.7	8.0	24.9	40.9	18.6	6.9	-	93.1
	Ti-I	0.0	1.1	11.4	33.3	35.9	18.4	-	81.6
	Ti-II	2.4	8.5	26.1	36.2	15.1	11.7	-	88.3
	Ti-III	3.0	9.1	22.2	36.4	19.9	9.3	-	90.7
	Ti-IV	6.8	12.1	37.2	36.9	5.8	1.1	-	98.9

Values described with identical letters do not differ significantly at $\alpha = 0.05$

A positive effect of titanium application on yielding of plants was also shown by Marcinek and Hetman [2008] for *Sparaxis tricolor* Ker-Gawl and Grajkowski and Ochmian [2007] for raspberry cutlivation. Michalski [2008] reported that in case of strawberry growing the effectiveness of plant nutrition with titanium is dependent on the year. Dobromilska [2007] stated that apart from an improvement of yielding a significant improvement was also found for vegetative growth in tomato, i.e. an increase in plant height, stem diameter and the number of leaves on a plant following foliar application with the above mentioned nutrient.

Side-dressing at the highest concentration of titanium had a significant effect on an increase in yielding of fruits with the greatest diameters (grades I, II and III) in comparison to the other tested combinations.

Macronutrient contents in leaves. A significant effect of Ti application was shown on an increase in index part contents of nitrogen, phosphorus, calcium and magnesium (the greatest contents of N, P, Ca and Mg at Ti-IV) and potassium (the greatest content at Ti-I) (tab. 2). In case of phosphorus, calcium and magnesium a general trend was observed in relation to the control for a reduction of nutrient contents at the application of the Ti-I level, and next a significant increase at increasing levels of titanium nutrition.

Table 2. The influence of titanium on the average content of macroelements in tomato leaves (in % of d.m.); (means from 2010–2011)

Ti level	N	P	K	Ca	Mg
Control	3.12 a	0.91 b	4.32 b	4.72 b	1.27 b
Ti-I	3.51 b	0.68 a	5.49 c	2.78 a	0.78 a
Ti-II	3.31 ab	0.92 b	3.88 ab	4.78 b	1.35 b
Ti-III	3.70 bc	0.99 c	4.35 b	4.73 b	1.46 b
Ti-IV	3.92 c	1.19 d	2.83 a	7.58 c	1.96 c

Values described with identical letters do not differ significantly at $\alpha = 0.05$

Malinowska and Kalembasa [2012] reported that titanium has a significant effect on a reduction of bioaccumulation of metallic micronutrients (iron and manganese). In all the tested combinations plant nutrition with nitrogen fell within the optimal range for this species, amounting to 2.8–4.2% N [Atherton and Rudisch 1986]. Except for the control combination recorded results also fell within the range of 3.5–5.0% N cited by the Agronomic Division… [2000]. Higher nitrogen contents in index parts of tomato plants than those recorded in this study were reported by Pawlińska and Komosa [2006]. In turn, phosphorus contents were markedly higher than those given by Atherton and Rudisch [1986], Kreij et al. [1990], Agronomic Division… [2000] or Jarosz and Dzida [2011]. Similar phosphorus contents were recorded in earlier studies by Pawlińska and Komosa [2006] and Kleiber et al. [2012]. The contents of potassium detected in this study are similar to the data supplied by the Agronomic Division… [2000] and Jarosz and Dzida [2011] (except for Ti-II and Ti-IV); at the same time they are markedly smaller than mean contents of this nutrient given by Pawlińska and Komosa [2006]. Levels of calcium in index parts of tomato plants comparable to those recorded in this study were given in an earlier paper by the authors of this study [Kleiber et al. 2012], while markedly lower contents (< 1.0% Ca) – by Sady et al. [1998]. Lower contents of calcium were also supplied in papers by Plank [1999] and Campbel [2000]. Contents of magnesium in index parts of plants were much greater than those recorded by Breś and Ruprik [2007] and Kleiber et al. [2012]. Optimal contents of magnesium in tomato leaves according to the Agronomic Division… [2000] should fall within the range of 0.35–1.0% Mg.

In conclusion it may be stated that in all analysed combinations, despite existing differences in nutrient contents in index parts of plants, no symptoms of their deficiency were observed and the appearance and yielding of plants were appropriate.

Contents of macronutrients in fruits. A general trend (except for Ti-II) was observed for an increase in nitrogen content in fruits with an increase in the applied titanium concentrations (tab. 3). In turn, the use of this nutrient did not modify contents of phosphorus and potassium in fruits. In case of magnesium the detected changes were multifaceted.

Table 3. The influence of titanium on the average content of macroelements in tomato fruits (in % of d.m.); (means from 2010–2011)

Ti level	N	P	K	Ca	Mg
Control	2.05 a	0.50 a	3.53 a	1.31 b	0.21 a
Ti-I	2.31 b	0.46 a	3.69 a	0.22 a	0.24 b
Ti-II	2.03 a	0.47 a	3.56 a	1.29 b	0.21 a
Ti-III	2.24 b	0.46 a	3.54 a	1.24 b	0.21 a
Ti-IV	2.66 c	0.46 a	3.70 a	1.23 b	0.25 b

Values described with identical letters do not differ significantly at $\alpha = 0.05$

Determined contents of nitrogen in fruits were markedly higher than those reported by Kleiber et al. [2012]. In turn, lower contents were given by Jarosz [2006]. In case of phosphorus contents they were consistent with the data cited by Kleiber et al. [2012]. Higher potassium contents were detected by Jarosz [2006] and Kleiber et al. [2012], while lower by Nzanza [2006]. Observed calcium contents in fruits (except for Ti-I) markedly exceeded contents of this nutrient reported by Kleiber et al. [2012]. Lower calcium levels in fruits under the influence of varied plant nutrition with potassium were recorded by Jarosz [2006]. In this study magnesium contents in fruits were lower than those given by Kleiber et al. [2012]. Jarosz [2006] reported contents in case of rockwool cultivation system within the range of 0.12–0.14% Mg.

Biological value of fruits. No significant effect of titanium was found on contents of dry matter and sugars in fruits, as well as their active acidity (tab. 4). At the same time a multifaceted significant variation was observed in vitamin C contents in fruits, as the detected contents ranged from 8.34 to 12.07 $mg \cdot 100\ g^{-1}$ (for Ti-II and Ti-I, respectively). Martinez Sanchez et al. [1993] recorded an increase in vitamin C content in fruits of peppers under the influence of foliar application of titanium. Skupień and Oszmiański [2007b] reported that there are significant cultivar-specific differences in the chemical composition of plants in response to foliar spraying of strawberry with titanium.

Table 4. The influence of titanium on the chosen parameters of biological values of tomato fruits (means from 2010–2011)

Ti level	Dry matter [%]	Vitamin C [mg·100 g f.w.$^{-1}$]	Total sugars [% in f.w.]	Actual acidity [pH]
Control	5.18 a	9.87 ab	2.69 a	4.65 a
Ti-I	5.22 a	12.07 c	2.83 a	4.80 a
Ti-II	5.06 a	8.34 a	2.62 a	4.67 a
Ti-III	5.04 a	11.36 c	2.64 a	4.59 a
Ti-IV	5.02 a	10.30 b	2.63 a	4.50 a

Values described with identical letters do not differ significantly at $\alpha = 0.05$

Similar contents of vitamin C were recorded in tomato fruits harvested from plants supplied with varied manganese levels (the author's unpublished data). Contents of dry matter and vitamin C recorded in fruits were lower than those reported by Jarosz [2006] (mean 6.94% d.m. and 22.09 mg·100 g f.w.$^{-1}$), as well as Nurzyński [2004] (mean 5.93% d.m. and 16.82 mg·100 g f.w.$^{-1}$). Total sugar contents were also slightly lower than those given by Jarosz [2006]. Similar sugar contents to those determined in this study were reported by Nurzyński [2004]. Kowalska [1996] claimed that the content of vitamin C in fruits is determined, among other things, by physical properties of the substrate and the applied nitrogen form. Golcz and Kozik [2004] reported that in case of lettuce factors influencing vitamin C content include the dose of nitrogen and the type of substrate used in the culture, while in peppers it is the type of nitrogen fertiliser and the level of potassium nutrition. Buczkowska and Najda [2002] stated that cultivar is another factor having a significant effect on the content of this vitamin.

Concluded it can say that titanium application via fertigation system as biostymulator in tomato nutrition influenced on the better nutrition with nitrogen, phosphorus, calcium and magnesium and worst in case of potassium. One of the possible reason is stimulating influence of titanium on the plant yielding (in case Ti-IV) – what in situation the highest content of potassium in fruits in case of Ti-IV – could be a reason of decreasing mentioned nutrient in leaves. Among the possible reason of significantly increasing of plant yielding in Ti-IV could be the increased magnesium content in leaves which is connect with chlorophyll content [Marschner 1995]. Influence of chlorophyll activity could press the increase most of macronutrient uptake – which was the highest in case of the most intensity of titanium fertilization. Titanium could also influenced on plant's enzyme activities [Dumon and Ernst 1988, Daood 1998].

CONCLUSIONS

As a result of the conducted investigations on the effect of titanium application in tomato growing in rockwool it was found that:

1. The application of titanium at an annual dose of 960 g Ti·ha^{-1} (Ti-IV) had a significant effect on the total and marketable yields.

2. Plant nutrition with titanium resulted in a significant increase in yielding of fruits with the greatest diameters (grades I, II and III) in comparison to the other tested combinations.

3. A significant effect of Ti application was shown for the contents in index parts of plants in case of the following nutrients: nitrogen, phosphorus, calcium, magnesium (the highest contents of N, P, Ca and Mg at Ti-IV) as well as potassium (the highest content at Ti-I).

4. A general trend was shown (except for Ti-II) for an increase in nitrogen content in fruits under the influence of titanium application at the simultaneous lack of effect on the contents of phosphorus and potassium.

5. No significant effect of titanium was shown for the contents of dry matter and sugars in fruits, or active acidity. At the same time a multifaceted significant variation was observed in vitamin C content in fruits.

6. In terms of the practical aspect, with particular emphasis on an improvement of yielding, it seems advisable to apply titanium as a biostimulant in tomato growing in rockwool.

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REFERENCES

Adamicki F., Dyśko J., Nawrocka B., Ślusarski C., Wysocka-Owczarek M., 2005. Metodyka integrowanej produkcji pomidorów pod osłonami. PIORIN, Warszawa.

Agronomic Division of the N.C. Department of Agriculture and Consumer Services Reference sufficiency ranges vegetable crops, 2000. [http://www.ncagr.gov/agronomi /saaesd/gtom.htm].

Alcaraz-Lopez C., Botia M., Alcaraz C.F., Riquelme F., 2003. Effects of foliar sprays containing calcium, magnesium and titanium on plum (*Prunus domestica* L.). J. Plant Physiol. 160, 1441–1446.

Alcaraz-Lopez C., Botia M., Alcaraz C.F., Riquelme F., 2004. Effect of foliar sprays containing calcium, magnesium and titanium on peach (*Prunus persica* L.) fruit quality. J. Sci. Food Agric. 84, 949–954.

Atherton J. G., Rudisch J., 1986. The tomato crop. Chapman and Hall. London, New York, 281–334.

Borkowski J., Felczyńska A., Stępowski J., Niekraszewicz A., 2006. Effect of different compounds Biochikol 020 PC, calcium nitrate, Tytanit and Pomonit on the healthiness and the yield of chinese cabbage. Polish Chitin Soc. Monograph. 11, 201–207.

Breś W., Ruprik B., 2007. Uprawa drobnoowocowych odmian pomidora szklarniowego we włóknie kokosowym przy zróżnicowanym nawożeniu azotem i potasem. Część IV. Ocena stanu odżywienia roślin. Acta Agrophys. 9(2), 297–305.

Buczkowska H., Najda A., 2002. A comparison of some chemical compounds in the fruit of sweet and hot pepper (*Capsicum annuum* L.). Folia Hort. 14 (2), 59–67.

Campbel C.R., 2000. References sufficiency ranges for plant analysis in the southern region. References sufficiency ranges vegetable crops. Southern Cooperative Series Bulletin, 394.

Dobromilska R., 2007. Wpływ stosowania Tytanitu na wzrost pomidora drobnoowocowego. Rocz. AR Pozn., 383, Ogrodnictwo 41, 451–454.

Daood H.G., Biacs P., Fehér, Hajdu F., Pais I., 1998. Effect of titanium on the activity of lipoxygenase J. Plant Nutr. 11,5, 505–516.

Dumon J.C., Ernst W.H.O., 1988. Titanium in plants. J. Plant Physiol. 133, 203–209.

Golcz A., Kozik E., 2004. Effect of several agrotechnical factors on vitamin C content in pepper (*Capsicum annuum* L.) and lettuce (*Lactuca sativa* L.). Rocz. AR Pozn. 356, Ogrodn. 37, 67–74.

Grajkowski J., Ochmian I., 2007. Influence of Tyree biostymulants on yielding and fruit quality of three primocane raspberry cultivars. Acta Sci. Pol., Hortorum Cultus, 6(2), 29–36.

Grenda A., 2003. Tytanit – aktywator procesów metabolicznych. In: Chemicals in sustainable agriculture. Czech Republic 4, 263–269.

Janas R., Szafirowska A., Kłosowski S., 2002. Effect of titanium on eggplant yielding. Veg. Crops Res. Bull. 57, 37–44.

Jankowski K., Dubis B., 2008. Biostymulatory w polowej produkcji roślinnej. Mat. Konf. Biostymulatory w nowoczesnej uprawie roślin. Warszawa. SGGW; Plantpress, 24.

Jarosz Z., 2006. Effect of different types of potassium fertilization on the chemical composition of leaves and fruits of greenhouse tomatoes grown in various substrates. Acta Sci. Pol., Hortorum Cultus 5(1), 11–18.

Jarosz Z., Dzida K., 2011. Effect of substratum and nutrient solution upon yielding and chemical composition of leaves and fruits of glasshouse tomato grown in prolonged cycle. Acta Sci. Pol., Hortorum Cultus 10(3), 247–258.

Kleiber T., Markiewicz B., Niewiadomska A., 2012. Organic substrates for intensive horticultural cultures. Yielding and nutrient status of plants. Microbiological parameters of substrates, Pol. J. Environ. Stud. 21(5), 1261–1271.

Kowalska I., 1996. Ocena przydatności mocznikowej, amonowej i azotanowej formy azotu nawozowego w uprawie szklarniowej pomidora przy zastosowaniu różnych podłoży ogrodniczych. Zesz. Probl. Post. Nauk Rol. 429, 175–180.

Kreij De C., Sonneveld C., Warmenhoven M.G., Straver N., 1990. Guide values for nutrient element content of vegetables and flowers under glass. Voedingsoplossingen Glastuinbouw 15.

Leskó K., István Pais S, Simon-Sarkadi L., 2002, Effect of cadmium and titanium-ascorbate stress on biological active compounds in wheat seedlings. J. Plant Nutrition 25, 11, 2571–2581.

Malinowska E., Kalembasa S., 2012. The field and content of Ti, Fe, Mn, Cu in celery leaves (*Apium graveolens* L. var. *dulce* Mill. Pers.) as a result of Tytanit application. Acta Sci. Pol., Hortorum Cultus 11(1), 69–80.

Marcinek B., Hetman J., 2008. The effect of foliage feeding on the structure of yield, dry weight content and macroelements in the corms of *Sparaxis tricolor* Ker-Gawl. Acta Sci. Pol., Hortorum Cultus 7(4), 89–99.

Marschner H., 1995. Mineral Nutrition of Higher Plants. 2nd ed. New York: Academic Press.

Martinez Sanchez F., Nunez M., Amoros A., Gimenez J. L., Alcaraz C.F., 1993. Effect of titanium leaf spray treatments on ascorbic acid levels of *Capsicum annuum* L. fruits, J. Plant Nutr. 16, 5, 975–981.

Michalski P., 2008. The effect of Tytanit on the yield structure and the fruit size of strawberry 'Senga Sengana' and 'Elsanta'. Annales UMCS, Agricultura 63(3), 109–118.

Nurzyński J., 2004. Wpływ koncentracji składników pokarmowych w podłożach z wełny mineralnej, torfu oraz piasku na plonowanie pomidora szklarniowego. X Ogólnopolskie Sympozjum Naukowe Efektywność stosowania nawozów w uprawach ogrodniczych, Kraków, 17–18 czerwca 2004; 261–268.

Nzanza B., 2006. Yield and quality of tomato as influenced by differential Ca, Mg and K nutrition. Department of Plant Production and Soil Science. Faculty of Natural and Agricultural Sciences, University of Pretoria, 103.

Pawlińska A., Komosa A., 2006. Wpływ podłoży i pożywek na stan odżywienia pomidora szklarniowego azotem, fosforem i potasem, Acta Agrophys. 7(3), 691–698.

Plank C.O. 1999, Plant Analysis handbook for Georgia. University of Georgia.
Sady W., Domagała I., Gustkowicz M., 1998 Ocena przydatności 5 odmian pomidora szklarniowego do uprawy na wełnie mineralnej. Zesz. Nauk. AR Kraków 333, 285–288.
Serrano M., Martinez-Romero D., Castillo S., Guillén F., Valero D., 2004. Effect of preharvest sprays containing calcium, magnesium and titanium on the quality of peaches and nectarines at harvest and during postharvest storage. J. Sci. Food Agric. 84, 1270–1276.
Skupień K., Oszmiański J., 2007a. Estimation of 'Tytanit' influence on selected quality traits of strawberry fruits. EJPAU, 10, 3, www.ejpau.media.pl.
Skupień K., Oszmiański J., 2007b. Influence of titanium treatment on antioxidants content and antioxidant activity of strawberries. Acta Sci. Pol., Technol. Aliment. 6(4), 83–94.
Wójcik P., 2002. Vigor and nutrition of apple trees in nursery as influenced by titanium sprays. J. Plant Nutr. 25, 5, 1129–1138.
Wójcik P., Wójcik M., 2001. Growth and nutrition of M.26 EMLA Apple rootstock as influence by titanium fertilization. J. Plant Nutr., 24, 10, 1575–1588.

ZASTOSOWANIE „TYTANITU" W SZKLARNIOWEJ UPRAWIE POMIDORA

Streszczenie. Szereg z prowadzonych obecnie badań dotyczy zastosowania biostymulatorów w intensywnej uprawie roślin. Jednym z pierwiastków mających cechy biostymulatora jest tytan. Celem przeprowadzonych badań była ocena wpływu stosowania tytanu na odżywienie roślin, ich plonowanie oraz zawartość makroskładników i wartość 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 $Ti{\cdot}ha^{-1}$), Ti-II (240 g $Ti{\cdot}ha^{-1}$), Ti-III (480 g $Ti{\cdot}ha^{-1}$), Ti-IV (960 g $Ti{\cdot}ha^{-1}$). Źródłem tytanu był nawóz „Tytanit" (Intermag Olkusz). W przeprowadzonych badaniach wykazano istotny wpływ stosowania tytanu przy poziomie Ti-IV na uzyskiwany plon całkowity i handlowy, przy jednoczesnym zwiększeniu plonu owoców o największych średnicach (klas I, II i III) w porównaniu z pozostałymi badanymi kombinacjami. Wykazano istotny wpływ Ti na wzrost zawartości w częściach wskaźnikowych roślin: azotu, fosforu, wapnia i magnezu (największa zawartość N, P, Ca i Mg oznaczony przy Ti-IV) oraz potasu (największa zawartość przy Ti-I). Stwierdzono generalną tendencję (za wyjątkiem Ti-II) do zwiększenia w owocach zawartości azotu pod wpływem stosowania tytanu, przy jednoczesnym braku oddziaływania na zawartość fosforu i potasu. W przypadku wapnia i magnezu oznaczone zmiany były wielokierunkowe. Nie wykazano istotnego wpływu tytanu na zawartość: suchej masy i cukrów w owocach, a także ich kwasowość czynną. Stwierdzono jednocześnie istotne zróżnicowanie zawartości witaminy C w owocach w zależności od poziomu żywienia roślin tytanem.

Słowa kluczowe: tytan, pomidor, plonowanie, skład chemiczny, części wskaźnikowe, owoce

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