ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Hortorum Cultus 13(1) 2014, 79-90*

THE STUDIES ON APPLYING OF EFFECTIVE MICROORGANISMS (EM) AND CRF ON NUTRIENT CONTENTS IN LEAVES AND YIELDING OF TOMATO

Tomasz Kleiber, Justyna Starzyk, Romuald Górski, Krzysztof Sobieralski, Marek Siwulski, Anna Rempulska, Agata Sobiak

Poznań University of Life Sciences

Abstract. The aim of this study was to evaluate the effect of applying Effective Microorganisms (EM), at a varied CRF (controlled release fertilizers) fertilization as starter fertilization, on macroelement contents in leaves and yielding of tomato grown in a peat substrate. Application of EM had significant effect – when applied either as seed inoculation or combined seed inoculation + spraying of plants on increase of total and commercial yields of tomato (35.8% and 40%; 44.6% and 35.9%, respectively). In contrast the application of CRF resulted in a significant increase in leaf contents of N (22.3–24.4%), K (13.6–16.6%) and Na (25%) at a simultaneous reduction of contents in case of Ca (9.9–15.7%) and Mg (21.9–23.9%) in comparison with the control combination. In view of environmental protection it is pointless to use starter fertilization in the form of slow-release fertilizers in case of a cyclical use of fertigation in crop growing. Due to the advantageous effect of Effective Microorganisms on crop yielding it seems advisable to consider their application in commercial crop growing.

Key words: Effective Microorganisms (EM), Controlled Release Fertilizers (CRF), tomato, yield, nutrient status

INTRODUCTION

Plants in a natural environment may exist in symbiosis with soil microorganisms. Such environments have been applied in completely artificial soilless cultures. Studies conducted far involved inoculating substrates using microorganisms such as *Aztobacter chroococcum* (CCM 1921), *Azospirillum brasilense* (CCM 3862), *Glomus mosseae* [Abdelaziz and Pokluda 2009] and Effective Microorganisms (EM) [Sangakkara et al. 2002, Valarini et al. 2003, Górski and Kleiber 2010]. EM contains an unspecified

Corresponding author: Tomasz Kleiber, Department of Plants Nutrition, Poznań University of Life Sciences, Zgorzelecka 4, 60-198 Poznań, e-mail: tkleiber@up.poznan.pl

amount of *Lactobacillus* sp., *Rhodopseudomonas* sp. and *Streptomyces griseus* [Daly and Stewart 1999, Higa 1994, 1996, 1998]. Studies conducted indicate that EM may influence development conditions for microorganisms living in a given soil, thus affecting plant growth and development [Higa 2003, Cóndor et al. 2007, Wielgosz et al. 2010, Frąszczak et al. 2012]. Moreover, Effective Microorganisms may have an effect on the availability of nutrients [Hussain et al. 1994, Gregorich et al. 1997, Sangakkara et al. 2002, Kee-Choon and Kremer 2007, Górski and Kleiber 2010]. One of the advantages of the above mentioned microbiological inoculant is connected with its spectrum of action, resulting from the diverse action of different groups of antagonistic microorganisms contained in that preparation, depending on the current soil conditions [Janas 2009]. Not all studies conducted have indicated a positive effect of their application in plant growing [Javaid and Shah 2010, Frąszczak et al. 2012, Ncube and Bvenura 2012]; however, there are numerous reports on their positive effects on crop yield [Li and Zhang 2000, Yan and Xu 2002, Sahain et al. 2007, Boligłowa and Gleń 2008, Górski and Kleiber 2010, Zydlik and Zydlik 2008].

Due to increasing cost of farming, commercial farmers are opting for simply cultivation measures, including the application of commercial fertilizers. One method involves use of starter fertilizer in the form of a single, basal application using slow-release fertilizers of the controlled release type (CRF). Suitability of CRF in vegetable growing was investigated by Komosa et al. [1998], Golcz and Komosa [2006], Golcz et al. [2009], Komosa and Golcz [2009].

The aim of the study was to determine the suitability of Effective Microorganisms (EM) and pre-vegetation CRF fertilizer on tomato growth, yield and on the plant nutrient status.

MATERIAL AND METHODS

Experiments on tomato (*Lycopersicon esculentum* Mill.) cv. 'Alboney F1' (Enza Zaden) were conducted during 2010–2011 at Marcelin Experimental Station at the Poznań University of Life Sciences (Poland). In each of the analyzed combination the control comprised plants, in which no starter CRF fertilization was used. The experiment was run in 12 combinations (3 fertilization levels × 4 EM levels) on 96 plants, in 4 replications in each year of the study. Plants were grown to have 6 clusters, which were regulated (to 6 fruits per cluster).

Plants were grown in containers (5 dm^3) filled with highmoor peat (Hartmann) with the following chemical composition (in $mg \cdot dm^{-3}$): $N\text{-}NH_4$ – 28; $N\text{-}NO_3$ – 7, P – 37, K – 11, Ca – 107, Mg – 21, $S\text{-}SO_4$ – 10, Fe – 50.2, Zn – 1.3, Mn – 1.3, Cu – 0.4, B – 0.43, Na – 11, Cl – 27, pH – 3.86, EC – 0.16 $mS \cdot cm^{-1}$ and bulk density of 460 $g \cdot dm^{-3}$. In order to optimize substrate reaction peat was limed based on the neutralization curve applying 7.5 g dolomite$\cdot dm^{-3}$. After liming the chemical composition of peat was as follows (in $mg \cdot dm^{-3}$): $N\text{-}NH_4$ – 35, $N\text{-}NO_3$ – trace amounts, P – 20, K – 18, Ca – 2045, Mg – 164, $S\text{-}SO_4$ – 25, Fe – 19.8, Zn – 1.8, Mn – 2.7, Cu – 0.4, B – 0.50, Na – 18, Cl – 29, pH – 6.31 and EC – 0.49 $mS \cdot cm^{-1}$.

It was studied 3 fertilization levels. In control combination no starter CRF fertilization was used. The tested CRF fertilizers were Osmocote 3–4 M and Osmocote 5–6 M, with the following chemical composition (respectively in %): 15 + 11 + 13 + 2 MgO + microelements and 15 + 10 + 12 + 2 MgO + microelements (denoted as Osmocote I and Osmocote II). Fertilizers were applied individually to each container within a given combination (in dose of 10 g × 5 dm^{-3} substrate), mixing it with the entire volume of the substrate.

The effect of varied Effective Microorganism (EM) application was investigated at varied CRF fertilization rates. Different form of Effective Microorganisms applied was studied (certified EM from Greenland) described as: (I) seed inoculation by 30-minute soaking in 10% EM aqueous solution directly before sowing (called as EM-inoculation), (II) plant spraying with 10% EM aqueous solution repeated twice in the vegetation period (mid-May and June) in each year of the study (described as EM spraying), (III) combined application of EM seed inoculation + EM spraying of plants.

In all the studied combinations plants were grown using fertigation. When preparing nutrient solutions water with the following chemical composition was used (in $mg \cdot dm^{-3}$): $N\text{-}NH_4$ – trace amounts (tr.), $N\text{-}NO_3$ – 0.3, $P\text{-}PO_4$ – 0.7, K – 3.6, Ca – 69.7, Mg – 15.3, $S\text{-}SO_4$ – 50.7, Fe – 0.084, Mn – 0.003, Zn – 0.37, B – 0.011, Cu – tr., Mo – tr., HCO_3 – 242.8, pH – 7.21 and EC – 0.708 $mS \cdot cm^{-1}$. In the experiments the nutrient solution applied in all the tested combinations had the following contents of nutrients (in $mg \cdot dm^{-3}$): $N\text{-}NH_4$ > 14, $N\text{-}NO_3$ – 160, $P\text{-}PO_4$ – 50, K – 287, Ca – 120, Mg – 60, $S\text{-}SO_4$ – 110, Fe – 0.75, Mn – 0.3, Zn – 0.37, Cu – 0.04, pH – 5.50 and EC – 2.50 $mS \cdot cm^{-1}$. The nutrient solution dose depended on the development phase of plants and weather conditions (1.0–2.5 dm^3 nutrient solution·day·$plant^{-1}$).

Fruits were harvested at regular intervals of 7 days from the last decade of July to end of August each year. The total yield comprised all harvested fruits, while commercial yield consisted of all fruits within the range of (Ø in cm): > 4.7 – < 10.2. Index parts of plants (the 8^{th}–9^{th} leaf counting from apex) were collected for chemical analyses. An average bulk sample within a given combination was composed of 5–6 leaves. The methodology of chemical analyses of the plantmaterial were given in a early study [Komosa et al. 2011]. Results of biometric measurements and chemical analyses were subjected to statistical analyses using Duncan test at the significance level p = 0.05.

RESULTS AND DISCUSSIONS

The effect of Effective Microorganisms (EM) on nutrient contents in leaves. It was found statistically unconfirmed increasing trend of the contents of nitrogen, phosphorus, potassium (except for EM-inoculation), calcium and magnesium in comparison to the control combination, in which Effective Microorganisms were not applied. Sodium contents determined in index parts of tomato were stable (tabs 1–6).

The effect of Osmocote fertilizer on nutrient contents in leaves. Analyses were conducted on slow-release fertilizers with a varied nutrient release time, i.e. 3–4 months (Osmocote I) and 5–6 months (Osmocote II). The control combination consisted of the culture, in which only fertigation was applied. The use of Osmocote fertilizers had

Table 1. The effects of fertilizer application and Effective Microorganisms (EM) on nitrogen content in index parts of tomato (8^{th}–9^{th} leaf from the apex) (% N)

Nutrient level (A)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)
Effective Microorganisms (B)	without EM			EM-inoculation			EM-spraying			EM-inoculation + EM-spraying		
	2.64 a	3.59 b	3.36 b	3.04 ab	3.44 b	3.57 b	2.90 a	3.64 b	3.54 b	2.89 a	3.61 b	3.58 b
Mean (B)	3.19 a			3.35 a			3.36 a			3.36 a		
Mean (A)	A-1 2.87 a			A-2 3.57 b			A-3 3.51 b					

Description for Tables 1–8: Values in line described with identical letters do not differ significantly at p = 0.05

Table 2. The effects of fertilizer application and Effective Microorganisms (EM) on phosphorus content in index parts of tomato (8^{th}–9^{th} leaf from the apex) (% P)

Nutrient level (A)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)
Effective Microorganisms (B)	without EM			EM-inoculation			EM-spraying			EM-inoculation + EM-spraying		
	0.55 a	0.60 a	0.57 a	0.58 a	0.61 a	0.55 a	0.53 a	0.63 a	0.63 a	0.55 a	0.63 a	0.61 a
Mean (B)	0.57 a			0.58 a			0.60 a			0.59 a		
Mean (A)	0.55 a			0.62 a			0.59 a					

Table 3. The effects of fertilizer application and Effective Microorganisms (EM) on potassium content in index parts of tomato (8^{th}–9^{th} leaf from the apex) (% K)

Nutrient level (A)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)
Effective Microorganisms (B)	without EM			EM-inoculation			EM-spraying			EM-inoculation + EM-spraying		
	3.46 a	3.97 b	3.80 b	3.40 a	3.73 a	3.62 a	3.39 a	3.93 b	4.09 b	3.27 a	4.14 b	3.87 b
Mean (B)	3.74 a			3.58 a			3.80 a			3.76 a		
Mean (A)	A-1 3.38 a			A-2 3.94 b			A-3 3.84 b					

Table 4. The effects of fertilizer application and Effective Microorganisms (EM) on calcium content in index parts of tomato (8^{th}–9^{th} leaf from the apex) (% Ca)

Nutrient level (A)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	OsmocoteI I (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)
Effective Microorganisms (B)	without EM			EM-inoculation			EM-spraying			EM-inoculation + EM-spraying		
	3.17 ab	3.43 b	2.89 a	3.86 b	3.25 b	3.31 b	3.83 b	3.36 b	2.84 a	3.66 b	3.05 a	3.22 ab
Mean (B)	3.16 a			3.47 a			3.34 a			3.31 a		
Mean (A)	A-1 3.63 b			A-2 3.27 a			A-3 3.06 a					

Table 5. The effects of fertilizer application and Effective Microorganisms (EM) on magnesium content in index parts of tomato (8^{th} – 9^{th} leaf from the apex) (% Mg)

Nutrient level (A)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)
Effective Microorganisms (B)	without EM			EM-inoculation			EM-spraying			EM-inoculation + EM-spraying		
	1.43 b	1.20 a	1.13 a	1.47 b	1.21 a	1.15 a	1.71 b	1.22 a	1.17 a	1.59 b	1.24 a	1.28 ab
Mean (B)	1.25 a			1.27 a			1.36 a			1.37 a		
Mean (A)	A-1 1.55 b			A-2 1.21 a						A-3 1.18 a		

Table 6. The effects of fertilizer application and Effective Microorganisms (EM) on sodium content in index parts of tomato (8^{th}–9^{th} leaf from the apex) (% Na)

Nutrient level (A)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)
Effective Microorganisms (B)	without EM			EM-inoculation			EM-spraying			EM-inoculation + EM-spraying		
	0.04 a	0.06 b	0.05 b	0.04 a	0.05 b	0.06 b	0.05 b	0.05 b	0.06 b	0.05 b	0.06 b	0.05 b
Mean (B)	0.05 a			0.05 a			0.05 a			0.05 a		
Mean (A)	0.04 a			0.05 b						0.05 b		

Table 7. The effects of fertilizer application and Effective Microorganisms (EM) on total yield of tomato grown in peat substrate (in kg·plant^{-1})

Nutrient level (A)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)
Effective Microorganisms (B)	without EM			EM-inoculation			EM-spraying			EM-inoculation + EM-spraying		
	3.08 a	3.36 a	3.60 b	4.57 c	4.63 c	4.45 c	3.55 b	3.70 b		3.49 b	4.41 c	4.78 c
Mean (B)	3.35 a			4.55 b			3.58 a			4.69 b		
Mean (A)	A-1 3.90 a			A-2 4.12 a			A-3 4.11 a					

Table 8. The effects of fertilizer application and Effective Microorganisms (EM) on commercial yield of tomato grown in peat substrate (in kg·plant^{-1})

Nutrient level (A)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)	Control (A-1)	Osmocote I (A-2)	Osmocote II (A-3)
Effective Microorganisms (B)	Without EM			EM-inoculation			EM-spraying			EM-inoculation + EM-spraying		
	2.57 a	2.69 a	3.02 ab	4.01 c	4.07 c	4.34 c	2.98 ab	3.07 b	2.87 a	3.48 b	3.87 bc	3.91 bc
Mean (B)	2.76 a			3.99 b			2.98 a			3.75 b		
Mean (A)	A-1 3.26 a			A-2 3.43 a			A-3 3.42 a					

a significant effect on nitrogen, potassium and sodium but reduced of the concentration of calcium and magnesium in index parts of tomato in comparison with the control combination (tabs 1–6).

A significant effect of the method of their application on the nutrient status of plants was shown in studies conducted to date with the application of EM. The use of EM in the form of inoculum added directly to the substrate in basil growing resulted in an increase in the contents of nitrogen and potassium, at a simultaneous deterioration of calcium and magnesium nutrition [Frąszczak et al. 2012].

Means for all the tested combinations of nutrient contents in leaves were as follows (% in d.m.): N 2.87–3.57, P 0.55–0.62, K 3.38–3.94, Ca 3.06–3.63, Mg 1.18–1.55 and Na 0.04–0.05. They were similar to those recommended by the Agronomic Division of the N.C. Department of Agriculture and Consumer Services [2000] amounting to (in % d.m.): N 3.5–5.0, P 0.30–0.65, K 3.5–4.5, Ca 1.0–3.0 and Mg 0.35–1.00. Earlier studies documented nitrogen contents similar to those determined in this study in leaves [Chohura 2000], at markedly lower contents of magnesium – in case of tomato cultivation in different substrates [Jarosz 2002].

Different factors differentiate the content of nutrient in tomato leaves. In case of tomato growing in inert media higher contents of nitrogen, potassium and calcium were determined in leaves, while contents of phosphorus and magnesium were lower [Chohura and Komosa 2003]. In turn, for tomato grown in peat contents of nitrogen were similar and simultaneous were recorded at greater contents of phosphorus, potassium and calcium and markedly lower contents of magnesium [Jarosz 2004]. Michałojć and Nowak [2000] showed similar contents of nitrogen, phosphorus, potassium, calcium and markedly lower contents of magnesium in leaves. In case of cultivation with the application of chloride-free potassium fertilization the following contents of nutrients (% in d.m. leaves) were determined in tomato leaves: N – 2.89, P – 0.86, K – 4.43, Ca – 5.23 and Mg – 0.42 [Jarosz 2006].

Moreover, a significant effect on the nutrition of plants with phosphorus, calcium and magnesium, confirming the results of this study, was also recorded for basil [Frąszczak et al. 2012].

The effect of Effective Microorganisms(EM) on yield. A significant improvement was observed on yield of tomato, which was connected with the application of EM (both in case of seed inoculation and a combined application of EM in the form of seed inoculation + plant spraying) in comparison with the control combination, in which EM were not used (tabs 7–8). Inoculation of seed with EM and spraying with it, increased plant yield by 40% as compared to the control. EM significantly modified commercial yield – the seed inoculation with EM cause improvement about 44.6% as compared to the control.

In the analyses conducted within this study significant factors affecting plants yields included the application of Effective Microorganisms in the form of seed inoculation as well as the above mentioned EM seed inoculation combined with plant spraying with their aqueous solution.

The beneficial effects of EM application on biometric parameters was shown in an earlier study conducted by Górski and Kleiber [2010] who used EM in roses and gerberas farming. The applicability of Effective Microorganisms was also found in the

cultivation of agricultural crops In case of maize it was found a positive combine effect of EM application with mineral fertilization on the yielding and protein content in grains [Shah et al. 2001]. It was found the efficiency of organic and mineral nutrient sources after EM application in cotton farming [Khaliq et al. 2006]. Boligłowa and Gleń [2008] proved the the effective protective Microorganisms (EM) against Septoria (*Septoria nodorum*) and brown leaf spot (*Drechslera tritici-repentis*) in wheat cultivation.

No direct mechanism that cause a significant increase in plant yielding was identified with EM application in this study. This may have been caused by the synergistic or antagonistic effect on the uptake of nutrients other than those determined in these analyses, and affecting plant growth and development. Such includes the capacity to produce high-affinity iron chelating siderophores, which may result in reduction of iron absorption by plants [Whipps 2001]. Effective Microorganisms may also have a similar effect on tomato growing to that exhibited by plant growth-promoting rhizobacteria (PGPR) on the stimulation of plant growth.

The effect of CRF on yielding. No significant effect of slow-release fertilizer application on total yield of tomato was observed in the conducted studies (tab. 8). The mean yield from all the tested combinations fell within the range of 3.90–4.12 kg·plant^{-1} (in case of the control combination and Osmocote I, respectively). Similarly, such an effect was not found for the commercial yield (3.42–3.43 kg·plant^{-1}) in comparison to the control (3.26 kg·plant^{-1}). Pawlińska and Komosa [2004] reported that application of nutrient solution with 20% higher EC (electrolitical conductivity) level than standard nutrient solution may cause – depending on the applied substrate – an increase (in case of organic substrates: sawdust and a mixture of peat and bark) or a reduction (in case of inert substrates: rockwool and expanded clay) of plant yielding.

Studies conducted to date on the application of slow-release fertilizers in horticulture have concerned mainly ornamental plants [Kozik and Henschke 2004, Szczepaniak and Kozik 2004]. In the growing of large-flowered larkspur and large-flowered tickseed a positive effect of Osmocote 3-4 M application in comparison to Osmocote 5-6 M was observed on plant growth and yield, e.g. the formation of a greater number of lateral shoots and flowers by plants [Kozik and Henschke 2004, Szczepaniak and Kozik 2004]. What is more, in view of environmental protection it is pointless to use starter fertilization in the form of slow-release fertilizers in case of cyclically applied fertigation in plant nutrition. This makes it possible to markedly reduce the consumption of mineral fertilizers. What is of particular interest, a significant effect on plant yielding was found for the application of Effective Microorganisms.

CONCLUSIONS

1. A significant effect was found for Effective Microorganisms applied in the form of seed inoculation, combined with seed inoculation + plant spraying on the total and commercial yields of tomato.

2. The use of CRF significantly increased the contents of nitrogen, potassium and sodium, however with simultaneous reduction of calcium and magnesium contents in index parts of tomato.

3. Taking into consideration the requirements of environmental protection it is pointless to use starter fertilization in the form of slow-release fertilizers in case of cyclical fertigation. Due to the advantageous effect of EM application on plant yielding it seems advisable to conduct further research focused on EM-application in commercial cultures.

REFERENCES

Abdelaziz M.E., Pokluda R., 2009. Response of cucumbers grown on two substrates in an open soilless system to inoculation with microorganisms. Acta Hort. 819, 157–164.

Agronomic Division of the N.C. Department of Agriculture and Consumer Services 2000 Reference sufficiency ranges vegetable crops. http://www.ncagr.gov/agronomi/saaesd/scsb394.pdf

Boligłowa E., Gleń K., 2008. Assessment of Effective Microorganism activity (EM) in winter wheat protection against fungal diseases. Ecol. Chem. Engin. A. 15(1–2), 23–27.

Chohura P., 2000. Zawartość składników pokarmowych w strefie korzeniowej, stan odżywienia i plonowanie pomidora szklarniowego w podłożach inertnych. Praca dokt. Wrocław, 35–83.

Chohura P., Komosa A., 2003. Nutrition status of greenhouse tomato grown in inert media. Part I. Macroelements. Acta Sci. Pol., Hortorum Cultus, 2(2), 3–13.

Cóndor A., González P., Lokare C., 2007. Effective Microorganisms: Myth or reality? Rev. Peru. Biol. 14(2), 315–319.

Daly M.J., Stewart D.P.C., 1999. Influence of Effective Microorganisms (EM) on vegetable production and carbon mineralization – a preliminary investigation. J. Sustain. Agric. 14(2/3), 15–25.

Frąszczak B., Kleiber T., Klama J., 2012. Impact of effective microorganisms on yields and nutrition of sweet basil (*Ocimum basilicum* L.) and microbiological properties of the substrate. Afr. J. Agricult. Res. 7(43), 5756–5765.

Gregorich E.G., Carter M.R., Doran J.W., Pankhurst C.E., Dwyer L.M., 1997. Biological attributes of soil quality. In: Soil quality for crop production and ecosystem health, Gregorich E.G., Carter M.R. (eds.). Elsevier, Amsterdam, 81–113.

Golcz A., Komosa A., 2006. Uwalnianie się azotu, fosforu i potasu z nawozu wolnodziałającego Osmocote Plus w uprawie papryki (*Capsicum annuum* L.). Acta Agroph. 7(3), 567–576.

Golcz A., Kozik E., Bosiacki M., 2009, Slow-release fertilizers in the production of horticultural plants Part. III. Effect of plant nutrition with slow-release and quick acting fertilizers and the harvest time on the biological value of sweet pepper (*Capsicum annuum* L.). J. Res. Applic. Agricult. Engine. 54(3), 40–42.

Górski R., Kleiber T., 2010. The effect of Effective Microorganisms (EM) on nutrient contents in substrate and development and yielding of rose (*Rosa* × *hybrida*) and gerbera (*Gerbera jamesonii*). Ecol. Chem. Engine. S. 17(4), 505–513.

Higa T., 1994. Effective microorganisms: A new dimension for nature farming. J.F. Parr et al. (eds.). Proc. the 2nd Int. Nature Farming Conf. USDA, Washington , 20–22.

Higa T., 1996. Effective microorganisms – Their role in Kyusei Nature Farming. J.F. Parr et al. (eds.). Proc. the 3rd Int. Nature Farming Conf. USDA, Washington, 20–23.

Higa T., 1998, Effective Microorganisms, concept and recent advances in technology. Proc. Conf. on Effective Microorganisms for a sustainable agriculture and environment. 4th Int. Conf. Kyusei Nature Farming, Bellingham – Washington, 247–248.

Higa T., 2003. EM Technology application in agriculture and environment protection. Proceed. of the 38 Int. Microbiological Symp. Effective Microorganisms (EM) in Sustainable Agriculture and Environmental Protection. SGGW, Rogów k. Łodzi, 17–18.

Hussain T., Ahmad R., Jilani G., Higa T., 1994. Applied EM technology. Nature Farming Research Center, University of Agriculture, Faisalabad, 1–6.

Janas R., 2009. The possibilities of using Effective Microorganisms in organic crop production systems. Prob. Agricult. Engine. 3, 111–117.

Jarosz Z., 2002. Plonowanie i skład chemiczny pomidora odmiany Cunero uprawianego na różnych podłożach w szklarni. Praca dokt. AR Lublin.

Jarosz Z., 2004. Skład chemiczny liści i owoców pomidora uprawianego w różnych podłożach w szklarni. Annales UMCS, sec. EEE, Horticultura 14, 31–36.

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.

Javaid A., Shah M.B.M., 2010. Growth and yield response of wheat to EM (Effective Microorganisms) and parthenium green manure. Afr. J. Biotech. 9(23), 3373–3381.

Khaliq A., Abbasi M., Hussain T., 2006. Effects of integrated use of organic and inorganic nutrient sources with Effective Microorganisms (EM) on seed cotton yield in Pakistan. Biores. Technol. 967–972.

Komosa A., Golcz A., Rokossowska E., 1998. Zastosowanie nawozów wolno- i szybkodziałających w uprawie papryki. Fol. Univ. Agric. Stetin. 190, Agricultura (72), 153–158.

Komosa A., Golcz A., 2009. Dynamics of macronutrient contents in the substrate with localized placement of controlled release fertilizer Osmocote Plus in the growing of pepper (*Capsicum annuum* L.). Acta Agroph. 14(1), 83–93.

Komosa A., Kleiber T., Wojtysiak P., 2011. Nutrition of lacy tree philodendron (*Philodendron bipinnatifidum* Schott et Endl.). Part II. Nutrient contents in leaves. Acta Sci. Pol. Hortorum Cultus 10(3), 99–111.

Kozik E., Henschke M., 2004. Wstępna ocena wzrostu i kwitnienia ostróżki wielkokwiatowej (*Delphinium grandiflorum* L.) w uprawie doniczkowej w zależności od nawożenia Osmocote Plus. Roczniki AR w Poznaniu 360, 111–117.

Li Z., Zhang H., 2000. Application of microbial fertilizers in sustainable agriculture. J. Crop Prod. 3, 1(5), 337–347.

Ncube L., Bvenura C., 2012. Effects of the integrated use of effective micro-organisms, compost and mineral fertilizer on greenhouse-grown tomato. Afr. J. Plant Sci. 6(3), 120–124.

Michałojć Z., Nowak L., 2000. Plonowanie i skład chemiczny pomidora uprawianego na podłożach inertnych. Mat. Konf. „Efektywność stosowania nawozów w uprawach ogrodniczych – Zmiany ilościowe i jakościowe w warunkach stresu". SGGW Warszawa 20–21 czerwca, 70–72.

Park K., Kremer R.J., 2007. Effects of a biological amendment on chemical and biological properties and microbial diversity in soils receiving different organic amendments. Korean J. Soil Sci. Fert. 40(4), 234–241.

Pawlińska A., Komosa A., 2004. Wpływ podłoży i pożywek na plonowanie pomidora szklarniowego. Roczniki AR w Poznaniu, 356, 173–180.

Sahain M.F.M., Abd El Motty E.Z., El- Shiekh M.H, Hagagg L.F., 2007. Effect of some biostimulant on growth and fruiting of anna apple trees in newly reclaimed areas. Rew. J. Agricult. Biol. Sci., Egypt. 3(5), 422–429.

Sangakkara R., 2002. The technology of effective microorganisms – case studies of application. Royal Agricultural College, Cirencester, UK Research Activities.

Shah S., Saleem M., Shahid M., 2001. Effect of different fertilizers and effective microorganisms on growth, yield and quality of maize. Int. J. Agricult. Biol. 4, 378–379.

Szczepaniak S., Kozik E., 2004. Wpływ rodzaju i objętości podłoża oraz nawozów o spowolnionym działaniu na wzrost młodych roślin nachyłka wielkokwiatowego. Roczniki AR w Poznaniu, 360, 157–161.

Valarini P.J., Diaz Alvares M.C., Gasco J.M., Guerrero F., Tokreshi H., 2003. Assessment of soil properties by organic matter and EM-microorganism incorporation. Rev. Bras. Ciênc. Solo 27, 3, 519–525.

Yan P.S., Xu H.L., 2002. Influence of EM Bokashi on nodulation, physiological characters and yield of peanut in nature farming fields. J. Sustain. Agricult. 19(4), 105–112.

Whipps J.M., 2001. Microbial interactions and biocontrol in the rhizosphere. J. Exp. Bot. 52, 487–511.

Wielgosz E., Dziamba S., Dziamba J., 2010. Effect of application of EM spraying on the populations and activity of soil microorganisms occurring in the root zone of spring barley. Pol. J. Soil Sci. 43, 1–12.

Zydlik P., Zydlik Z., 2008. Impact of biological effective microorganisms (EM) preparations on some physico-chemical properties of soil and the vegetative growth of apple-tree rootstocks. Nauka Przyr. Technol. 2, 1, 4.

BADANIA NAD ZASTOSOWANIEM EFEKTYWNYCH MIKROORGANIZMÓW I NAWOZÓW TYPU CRF NA ZAWARTOŚĆ SKŁADNIKÓW POKARMOWYCH W LIŚCIACH I PLONOWANIE POMIDORA

Streszczenie. Celem podjętych badań była ocena wpływu stosowania efektywnych mikroorganizmów, przy zróżnicowanym nawożeniu nawozami typu CRF (o kontrolowanym uwalnianiu składników) jako nawożeniu startowym, na zawartość makroelementów w liściach oraz plonowanie pomidora uprawianego w substracie torfowym. Efektywne mikroorganizmy wpływały istotnie – stosowane zarówno w postaci inokulowania nasion, jak i łącznego inokulowania nasion i opryskiwania roślin – na wzrostu plonu ogólnego i handlowego pomidora (odpowiednio 35,8% i 40%; 44,6% i 35,9%). Dla porównania zastosowanie nawozów CRF wpływało z kolei na istotny wzrost zawartości w liściach: N (22,3–24,4%), K (13,6–16,6%), Na (25%) przy jednoczesnym obniżeniu zawartości Ca (9,9–15,7%) i Mg (21,9–23,9%), w porównaniu z kombinacją kontrolą. Biorąc pod uwagę ochronę środowiska naturalnego, bezcelowe jest stosowanie nawożenia startowego w postaci nawozów wolnodziałających w przypadku cyklicznego stosowania fertygacji w uprawie roślin. Ze względu na korzystny wpływ efektywnych mikroorganizmów na plonowanie roślin wydaje się celowe rozważenie ich stosowania w uprawach produkcyjnych.

Słowa kluczowe: efektywne mikroorganizmy (EM), nawozy wolnodziałające o kontrolowanym działaniu, pomidor, plonowanie, stan odżywienia

Accepted for print: 5.07.2013