Journal of Elementology ISSN 1644-2296

Buczkowska H., Michałojć Z., Konopińska J., Kowalik P. 2015. *Content of macro- and microelements in sweet pepper fruits depending on foliar feeding with calcium.* J. Elem., 20(2): 261-272. DOI: 10.5601/jelem.2014.19.3.712

ORIGINAL PAPERS

CONTENT OF MACRO- AND MICROELEMENTS IN SWEET PEPPER FRUITS DEPENDING ON FOLIAR FEEDING WITH CALCIUM

Halina Buczkowska[1], Zenia Michałojć[2], Joanna Konopińska[2], Piotr Kowalik[2]

[1]Chair of Vegetable Crops and Medicinal Plant
[2]Chair Cultivation, Fertlization Horticultural Plants
University of Life Sciences in Lublin

Abstract

Sweet pepper belongs to vegetables with high biological value, characteristic taste and health-promoting features, which depend on the content of many elements with antioxidant capacity. Pepper fruits are an important source of mineral components for people. The aim of this study was to determine the effect of different foliar feeding regimes with the use of calcium on the content of macro- and microelements in sweet pepper fruits. The experiment with the sweet pepper cultivar Caryca F_1 was carried out under field conditions in 2010-2011. Various calcium preparations: $Ca(NO_3)_2$, Insol Ca, Librel Ca, were applied in plant nutrition. The evaluated preparations were sprayed 3 and 5 times, in the concentration of 1%, until complete wetness of the plants. Control fields were sprayed with water. No significant influence of the examined factors on the dry matter content (%) was recorded in the fruits of cv. Caryca F_1 sweet pepper cultivated in a field. However, the influence of the applied calcium preparations on the content of N-total, P, Ca, Fe, Zn, Cu in pepper fruits was shown to vary. After an application of $Ca(NO_3)_2$ higher concentrations of K, Zn, Cu were demonstrated; an application of Insol Ca stimulated a higher content of K and Cu; more K, Fe, Zn and Cu occurred in the fruit after feeding with Librel Ca, and the content of P was lower after an application of Insol Ca and Librel Ca, all versus the control. The different number of treatments did not have any significant effect on the chemical content of pepper fruits, except for Fe and Mn, where 5 treatments increased the content of these elements in pepper fruits. The positive influence of the applied calcium preparations and of the number of treatments on the accumulation of Ca in pepper fruits were proven. For example, 5 treatments were demonstrated to have increased the calcium content in fruits by an average 25.3%, and 3 treatments raised the above trait by 15.3% above the control.

Key words: *Capsicum annuum* L., foliar feeding, calcium, mineral components.

dr hab. Halina Buczkowska prof. nadzw., Chair of Vegetable Crops and Medicinal Plant, Akademicka 13, 20-950 Lublin, Poland, e-mail: halina.buczkowska@up.lublin.pl

INTRODUCTION

Field cultivation of sweet pepper for the fresh vegetable market as well as for processing has been playing an important economic role in commercial vegetable production in Poland over the recent years (Gajc-Wolska, Skapski 2002). Sweet pepper is a valuable vegetable with unique health-promoting and taste properties, which it ows to the presence of several compounds with antioxidant activity (Guil-Guerrero et al. 2006, Marin et al. 2009). High concentrations of mineral components impor-tant for people have been identified in pepper (Rubio et al. 2002, Golcz, Kujawski 2004, Jadczak, Grzeszczuk 2004, Pokluda 2004, Guil-Guerrero et al. 2006, Perez-Lopez et al. 2007, Martinez et al. 2007, Bernardo et al. 2008, Jadczak et al. 2010, Buczkowska, Michałojć 2012, Zaki et al. 2013). What ensures a good marketable yield of sweet pepper from a field is the selection of a cultivar suitable for cultivation in less favorible enviroment and the application of yield intensifying treatments of which mineral feeding of plants and its level are the most important (Golcz 2001, Golcz et al. 2004, Michałojć, Horodko 2006, Medina-Lara et al. 2008, Ghoname et al. 2009, Kowalska, Sady 2012, Michałojć, Dzida 2012). In sweet pepper cultivation, one of the most frequent disturbances in plant nutrition are the symptoms of blossom-end rot on fruits (BER), which disqualifies fruits from human consumption (Aleksander, Clough 1998, Kowalska, Sady 2012, Michałojć, Dzida 2012, Paradikowič et al. 2013). It was proven that the occurrence of blossom-end rot (BER) on fruit of vegetables from the Solanaceae family can be prevented through the foliar supplementation of calcium. The fastest and most effective way to limit cases of calcium deficiency is the direct application of a calcium preparation by spraying those parts of plants where Ca translocation is limited, that is leaves and fruits (Marcelius, Ho 1999, Michałojć, Horodko 2006, Casado-Vela et al. 2007, Kowalska, Sady 2012, Michałojć, Dzida 2012).

The aim of the present study was to demonstrate the effect of differentiated foliar feeding with calcium on the content of macro- and microelements in sweet pepper fruits cultivated in field.

MATERIAL AND METHODS

The experiments were carried out in 2010 and 2011 on fields of a private farm in Zezulin (51.35°N, 22.85°E) near Lublin, on grey-brown podsolic soil from loess material on chalk marls, with the 1.8% content of organic matter in the arable layer. Fruits of cv. Caryca F_1 sweet pepper were analysed. In both years, winter wheat was used as the preceding crop. In autumn, organic fertilization consisting of manure in the amount of 30 t ha^{-1} was applied. The content of mineral components in soil in 2010 and 2011 was the following: N 30, 32; P 180, 160; K 180, 160; Ca 2000, 2200; Mg 40, 50 mg dm^{-3} at pH 6.5 and 6.8, respectively. Mineral fertilization with nitrogen in the amount of 50 kg ha^{-1} (2010) and 60 kg ha^{-1} (2011) was applied prior to the transplanting of seedlings. Potted pepper seedlings were grown in a greenhouse, in line with a commonly accepted cultivation technology designed for this species. Seedlings were transplanted on a field in the 3rd decade of May, at the plant density of 4.26 plants per m^2.

The study examined the effect of two factors: type of calcium preparation and number of treatments. The following calcium preparations were used:

- $Ca(NO_3)_2$: 19% Ca; 15.5% N;
- Insol Ca: 9.8% Ca; 0.1% Mn; 0.05% B; 0.05% Zn; 0.01% Cu;
- Librel Ca: 9.0% Ca as a chelated EDTA;
- control.

The above preparations were applied in three and five treatments.

The agricultural experiment was carried out in random blocks with 4 replicates. The area of each plot equaled 9.4 m^2, and 40 plants were cultivated per plot.

Foliar feeding was performed by application of each preparation in the concentration of 1% until total wetness of plants. Control fields were sprayed with water. Feeding started when first pepper fruits reached the diameter of 1-2 cm (1st decade of July). 3 treatments of feeding with calcium were performed in 2010: 2 July, 24 July, 14 August, and in 2011: 5 July, 26 July, 18 August. 5 treatments in 2010: 2 July, 13 July, 24 July, 3 August, 14 August, and in 2011: 5 July, 16 July, 26 July, 7 August, 18 August. Samples of mature pepper fruits were collected for analysis at full fruiting. Dry matter was determined in raw fruits with the drier method at 105°C. The N-total was determined in dried fruit with the Kiejdahl's method, and after burning at temperature of 550°C, the following were determined: P – colorimetrically with ammonium vanadium molybdate; K, Ca, Mg, Fe, Mn, Zn, Cu with the ASA method (Perkin – Elmer). The analyses of the above components were performed in 3 replications. Because the results of the Mg, F, Mn, Zn and Cu content in pepper fruits in 2010 and 2011 were comparable, in the present study they are recorded as mean values of the two years of the experiment. The results were statistically processed with the variance analysis method as a 2-factor experiment. Significance of differences was evaluated by the T-Tukey's multiple confidence intervals at the confidence level of 5%.

RESULTS AND DISCUSSION

No evident influence of the foliar feeding with calcium on the share of dry matter (%) in sweet pepper fruits of cv. Caryca F_1 was proven. In 2010, significantly more dry matter (7.59%) was recorded in the fruit obtained from the control plants than from plants fed with the calcium preparations (7.07%) – Table 1. In the second year of the experiment, no significant influence of the examined factors on the dry matter accumulation in fruits (8.54-8.57%) was recorded. Nonetheless, significant differences were noted in the dry matter content in pepper fruit between the two years. Significantly more dry matter was contained in pepper fruits in 2011, when the total rainfall from May to September reached 369.7 mm, whereas in 2010 it amounted to 575.1 mm. The total rainfall in the period of growing and maturing of fruit doubled the average value of several years, while in September 2011 the total rainfall was 22-fold less than the multi-year average value. The lower content of dry matter in fruit should be explained by a greater amount of water available in the period of intensive fruit growth and by better hydration of tissues. The results obtained from the present study concerning the dry matter content differ from those qouted for cultivars grown in field under the Polish climate. In numerous studies on pepper cultivated in field, the dry matter content in fruit varied from 9.20% to 11.65% (Buczkowska, Najda 2002, Gajc-Wolska, Skąpski 2002, Gajc-Wolska et al. 2005, Jadczak et al. 2010, Buczkowska, Michałojć 2012).

The N-total content in pepper fruits of cv. Caryca F_1 ranged between 18.70 and 20.70 g N-tot. kg^{-1} d.m. and was significantly diversified in years 2010 (average 19.17 g N-tot. kg^{-1} d.m.) and 2011 (average 20.53 N-tot. kg^{-1}) – Table 1. On the basis of the results, no evident influence of foliar feeding with calcium on N-total content in sweet pepper fruits was proven. In 2010, significantly more N-total was recorded in fruits of plants which were fed with calcium nitrate (19.48 g N-tot. kg^{-1} d.m.) and Insol Ca (19.40 g N-tot. kg^{-1} d.m.) as compared to fruits of plants treated with Librel Ca (18.85 g N-tot. kg^{-1} d.m.) and to control plants (18.95 g N-tot. kg^{-1} d.m.). In the second year, significantly more N-total was recorded in fruit of plants after the application of Librel Ca (21.33 g N-tot. kg^{-1} d.m.) and in objects not treated with calcium (20.65 g N-tot. kg^{-1} d.m.) as compared to fruits of plants treated with calcium nitrate (20.00 g N-tot. kg^{-1} d.m.) and Insol Ca (20.12 g N-tot. kg^{-1} d.m.). No significant influence of the number of calcium treatments on the content of N-total in sweet pepper fruits was shown, although it is worth mentioning that in 2011 a higher N-total content was determined in fruits obtained from plants treated with calcium applications 5 times. Slightly less of the component was recorded in fruits harvested in 2010 (average 19.17 g N-tot. kg^{-1} d.m.) than in 2011 (average 20.53 g N-tot. kg^{-1}.) It should be emphasized that this correlation can be attributed to the heavy rainfall during the fruit growing season (Table 2). Nitrogen content in fruits of cv. Caryca F_1 pepper is similar (20.80-24.87 g N-tot. kg^{-1} d.m.) to the content recorded by Buczkowska, Michałojć (2012) in fruits of cv. Red Knight F_1 grown in field and in a greenhouse. It is slightly lower (24.40-28.60 g N-tot. kg^{-1} d.m.) than reported by Michałojć, Horodko (2006) in fruits of cv. Rebeka F_1 from an experiment concerning foliar feeding with calcium in greenhouse cultivation. Jadczak, Grzeszczuk (2004) also determined similar

Table 1

Dry matter (%) and content of N-total, P, K (g kg^{-1} d.m.) in the sweet pepper fruit depending on the kind and the number of treatments of calcium fertilizer

Kind of calcium fertilizer	Number of treatments	Dry matter			N-total			P			K		
		2010	2011	mean	2010	2011	mean	2010	2011	mean	2010	2011	mean
$Ca(NO_3)_2$	three	6.76	8.54	7.65	19.85	19.55	19.70	2.65	2.30	2.48	23.75	27.15	25.45
	five	7.37	8.60	7.99	19.10	20.45	19.78	2.65	2.25	2.45	22.30	26.65	24.48
	mean	7.07	8.57	7.82	19.48	20.00	19.74	2.65	2.27	2.46	23.03	26.90	24.97
Insol Ca	three	7.40	8.54	7.97	19.35	19.65	19.50	2.65	2.30	2.48	22.60	27.25	24.92
	five	6.74	8.75	7.75	19.45	20.60	20.02	2.50	2.25	2.38	23.05	27.05	25.05
	mean	7.07	8.65	7.86	19.40	20.12	19.76	2.58	2.28	2.43	22.82	27.15	24.98
Librel Ca	three	6.98	8.58	7.78	19.00	20.75	19.88	2.25	2.20	2.22	23.70	27.30	25.50
	five	7.17	8.54	7.86	18.70	21.90	20.30	2.55	2.35	2.45	20.30	26.80	24.55
	mean	7.07	8.56	7.82	18.85	21.33	20.09	2.40	2.27	2.33	23.00	27.05	25.02
Control	three	7.58	8.46	8.02	18.90	20.60	19.75	2.60	2.40	2.50	22.70	24.80	23.75
	five	7.61	8.40	8.00	19.00	20.70	19.85	2.60	2.40	2.50	22.70	25.60	24.15
	mean	7.59	8.43	8.01	18.95	20.65	19.80	2.60	2.40	2.50	22.70	25.20	23.95
Mean	three	7.23	8.53	7.88	19.28	20.14	19.71	2.54	2.30	2.42	23.19	26.63	24.91
	five	7.22	8.57	7.89	19.06	20.91	19.99	2.58	2.31	2.45	22.09	26.53	24.31
Total mean		7.22	8.55	7.88	19.17	20.53	19.85	2.56	2.30	2.43	22.64	26.58	24.61
$LSD_{0.05}$													
Kind of calcium fertilizer (A)		0.102	n.s	n.s.	0.105	0.170	n.s.	0.088	0.051	0.149	n.s.	0.396	n.s.
Number of treatments (B)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.193	n.s.	n.s.
Years (C)				0.264			0.506			n.s.			1.366
Interaction:													
(A × B)		0.174	n.s.	n.s.	0.180	0.299	n.s.	0.150	0.087	n.s.	0.631	1.852	n.s.
(A × C)				0.839			1.609			n.s.			n.s.
(B × C)				0.497			0.952			n.s.			2.574

Table 2

Mean monthly air temperature and sum of rainfalls in years 2010-2011
in the period of pepper vegetation

Teperature (C°)	Year	Month				
		May	June	July	August	September
	2010 2011	14.5 14.3	18.0 18.6	21.6 18.4	20.2 18.8	12.5 15.2
Mean for 1951-2000		13.0	16.5	17.9	17.3	12.9
Sums of rainfalls (mm)	2010 2011	156.7 42.2	65.6 67.8	101.0 189.0	132.8 65.3	119.0 5.4
Mean for 1951-2000		58.3	65.8	78.0	69.7	52.1

N-total content in hot pepper fruit (16.40-20.10 g N-tot. kg^{-1} d.m.), while in another study by Jadczak et at. (2010), the total nitrogen content in fruits of sweet pepper mixed cultivars of Israelian origin was 19.51-20.64 g N-tot. kg^{-1} d.m. Comparable N-total (19.2-29.7 N-og. kg^{-1} d.m.) was obtained by Golcz , Kujawski (2004), Golcz et al. (2004*a*) and Berova et al. (2013).

The P content in sweet pepper fruits remained in the range between 2.20 to 2.66 g P kg^{-1} d.m. (Table 1). The present study indicated a significant influence of foliar feeding with calcium on P accumulation in sweet pepper. In 2010, significantly less P was found in fruits of plants fed with Librel Ca (2.40 g P kg^{-1} d.m.) as compared to other objects (2.58-2.65 g P kg^{-1} d.m.). It is worth noting that in the second year of experiment the P content in fruit from the control objects was higher (2.40 g P kg^{-1} d.m.) than from those treated with calcium preparations (2.27-2.28 g P kg^{-1} d.m.). No influence was noted of the number of calcium treatments, nor years of research on the P content in fruits. Our results are comparable with those published by Kmiecik, Lisiewska (1994), Golcz, Kujawski (2004), Michałojć, Horodko (2006). Higher P content (2.60-3.60 g P kg^{-1} d.m.) was demonstrated by Jadczak, Grzeszczuk (2004) and by Jadczak et al. (2010), in sweet pepper fruits of hybrid cultivars and in hot pepper. However, Gajc-Wolska et al. (2005) recorded a significantly lower P content (0.38-0.45 g P kg^{-1} d.m.) in fruits of new sweet pepper hybrid cultivars. The above results indicate that, in a moderate climate, plants accumulate less P (3.05-4.53 g P kg^{-1} d.m.) than in the favorable temperatures of Spain (Rubio et al. 2002, Guil-Guerrero et al. 2006, Bernardo et al. 2008, Zaki et al. 2013).

The K content in pepper fruits ranged from 22.30 to 27.30 g K kg^{-1} d.m. (Table 1). No evident influence was observed of the applied calcium preparations on the K content in pepper fruits. Significant differences were recorded in the content of this component between the research years. In 2010, an average of 22.64 g K kg^{-1} d.m. was recorded, but in 2011 it went up to 26.58 g K kg^{-1} d.m. Moreover, in each years of the research, significantly less K was recorded in fruits treated 5 times with calcium in the chelated form (Librel Ca). This relationship indicates that Ca applied in that form limited the accumulation of K in fruit tissues. Similar K content of 19.00 to 30.00 g K kg^{-1} d.m. in pepper fruits was observed by several authors: Kmiecik, Lisiewska (1994) in fruits of sweet pepper cultivars suitable for processing, Pokluda (2004) in fruits of Czech cultivars in field cultivation in Moravia, Gajc-Wolska et al. (2005) in fruits of hybrid forms, Golcz, Kujawski (2004) in hot pepper, Michałojć, Horodko (2006) in fruits ofcv. Rebeka F_1 in greenhouse cultivation, Jadczak Grzeszczuk (2004), Jadczak et al. (2010) in selected cultivars of sweet and hot pepper cultivated in field in the conditions of Western Pomerania. More K (33.30-36.5 g K kg^{-1} d.m.) in fruits of cv. Delphin F_1 was observed by Golcz (2001), who evaluated effects of diversified fertilizing with potassium on yielding of sweet pepper cultivated in a greenhouse. As indicated in available literature, there is a comparable K content in fruits of pepper cultivated in the warm climate zone (Guil-Guerrero et al. 2006, Martinez et al. 2007, Perez-Lopez et al. 2007, Bernardo et al. 2008, Medina-Lara et al. 2008, Paradikovič et al. 2013, Zaki et al. 2013).

The Ca content in fruits ranged between 360 and 530 mg Ca kg^{-1} d.m. (Figure 1). No significant differences were recorded in the Ca content in fruits between the years of the research. However, positive influence of foliar feeding with Ca preparations on the Ca content in sweet pepper fruits was observed. In 2010, the calcium content in fruit of plants fed with the Ca preparations ranged between 440 mg Ca kg^{-1} d.m. (Librel Ca) and 502 mg Ca kg^{-1} d.m. ($Ca(NO_3)_2$) and was significantly higher compared to the content in fruits of plants that were not fed with calcium (395 mg Ca kg^{-1} d.m.). However, in 2011, the content of this component ranged between 430 and 493 mg Ca kg^{-1} d.m. in objects fed with calcium and 365 mg Ca kg^{-1} d.m. in

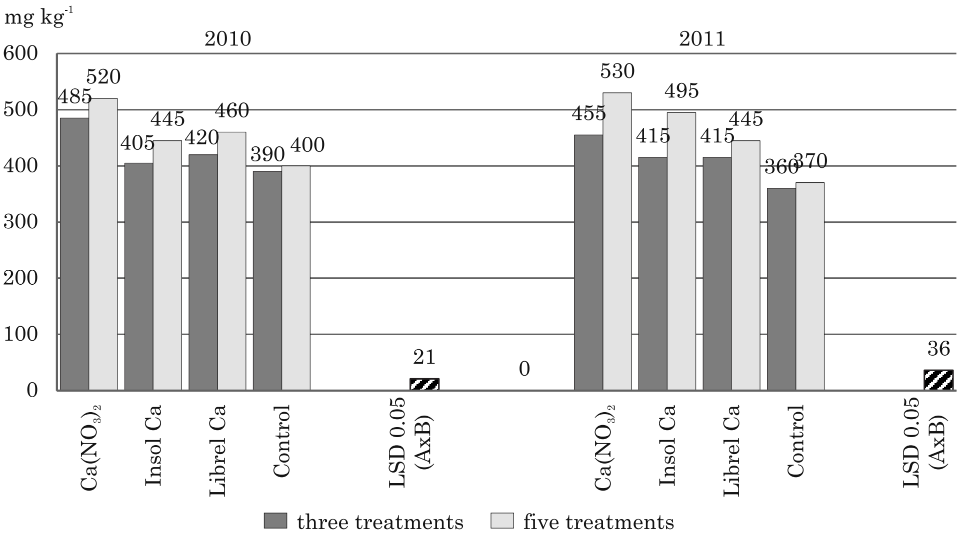

Fig 1. Content of calcium in the sweet pepper fruit depending on the kind the number of treatments calcium fertilizer

fruits of the control plants. What draws attention is the higher content of Ca, which penetrated fruit through the skin when Ca was applied in the form of calcium nitrate (average mg Ca kg^{-1} d.m.) compared to the form of Isol Ca (average 440 mg Ca kg^{-1} d.m.) or Librel Ca (average 435 mg Ca kg^{-1} d.m.). These results confirm easier penetration through plant tissues of calcium in the mineral rather than chelated form. It was demonstrated that the number of foliar feeding treatments with calcium had positive influence on the Ca content in fruits of pepper cultivated in field. After 5 treatments with Ca, the calcium content grew by average 25.3%. With 3 treatments, the average increase was 15.3% compared to the control. Comparable calcium levels (305-800 mg Ca kg^{-1} d.m.) in pepper fruits were recorded by MARTINEZ et al. (2008), BUCZKOWSKA, MICHAŁOJĆ (2012), KOWALSKA, SADY (2012); lower (106-220 mg Ca kg^{-1} d.m.) by KMIECIK, LISIEWSKA (1994), MICHALIK (2000), RUBIO et al. (2002), GOLCZ, KUJAWSKI (2004), GAJC-WOLSKA et. al. (2005). More calcium (900-2620 mg Ca kg^{-1} d.m.) in pepper fruits was recorded by other authors (BUBICZ et al. 1999, GOLCZ 2001, GOLCZ et. al. 2004*b*, POKLUDA 2004, GUIL-GUERRERO et al. 2006, PEREZ-LOPEZ et al. 2007, BERNARDO et al. 2008, JADCZAK et. al. 2010, PARADIKOVIČ et al. 2013, ZAKI et al. 2013).

The Mg content in the fruit of cv. Caryca F_1 reached 0.884 g Mg kg^{-1} d.m. on average (Table 3). In neither years, significant influence of feeding sweet pepper with calcium on the magnesium content in fruits was recorded. Similar or close magnesium content in pepper fruit was noted by other authors (BUBICZ et al. 1999, MICHALIK 2000, MICHAŁOJĆ, HORODKO 2006, CASADO-VELA et al. 2007, GAJC-WOLSKA et al. 2007, MARTINEZ et al. 2007, JADCZAK et al. 2010, BUCZKOWSKA, MICHAŁOJĆ 2012). Higher Mg content (1.00-3.18 g Mg kg^{-1} d.m.) was recorded by GOLCZ (2001), GOLCZ et al. (2004*a*), POKLUDA (2004), GUIL-GUERRERO et al. (2006), BERNARDO et al. (2008), PARADIKOVIČ et al. (2013), ZAKI et al. (2013), while less Mg (0.104-0.160 g Mg kg^{-1} d.m.) was detected by MICHALIK (2000) and RUBIO et al. (2002).

The Fe content in sweet pepper fruits ranged between 42.44 and 47.32 mg Fe kg^{-1} d.m. The type of the applied calcium preparation differentiated the Fe content in sweet pepper. Significantly more Fe (average 45.22 mg Fe kg^{-1} d.m.) was recorded in fruits of plants which were fed with calcium in Librel Ca compared to the content of this micronutrient in fruits from other treatments. Regardless of the type of Ca preparation, significantly more Fe was recorded in fruits from plants which had received 5 treatments with calcium (average 44.42 mg Fe kg^{-1} d.m) compared to 3 treatments (average 43.67 mg Fe kg^{-1} d.m.). The Fe content in the range of 40 to 100 mg Fe kg^{-1} d.m. in pepper fruits was recorded in several studies (MICHALIK 2002, JADCZAK, GRZESZCZUK 2004, CASADO-VELA et al. 2007, GUIL-GUERRERO et al. 2006, BERNARDO et al. 2008, MARTINEZ et al. 2008, PARADKOVIĆ et al. 2013). A considerably lower content was observed by KMIECIK, LISIEWSKA (1994) – 3.16-4.04 mg Fe kg^{-1} d.m., RUBIO et al. (2002) – 3.1 mg Fe kg^{-1} d.m., and a very high level was reported by ZAKI et al. (2013) – 200-300 mg Fe kg^{-1} d.m. and JADCZAK et al. (2010) – 365-600 mg Fe kg^{-1} d.m.

Table 3

Content of mineral compounds: Mg (g kg^{-1} d.m.), Fe, Mn, Zn, Cu (mg kg^{-1} d.m.) in the sweet pepper fruit depending on the kind and the number of treatments of calcium fertilizer (mean for years 2010-2011)

Kind of calcium fertilizer	Number of treatments	Mg	Fe	Mn	Zn	Cu
$Ca(NO_3)_2$	three	0.888	43.39	8.63	15.03	3.63
	five	0.880	43.99	8.79	14.75	3.83
	mean	0.884	43.69	8.72	14.89	3.73
Insol Ca	three	0.883	44.36	8.53	14.61	3.52
	five	0.885	42.44	8.79	14.61	3.14
	mean	0.884	43.40	8.66	14.61	3.33
Librel Ca	three	0.888	43.12	8.59	14.68	3.38
	five	0.880	47.32	8.81	14.98	3.39
	mean	0.884	45.22	8.70	14.83	3.38
Control	three	0.880	43.80	8.68	14.47	3.12
	five	0.885	43.94	8.68	14.39	3.13
	mean	0.883	43.87	8.68	14.43	3.13
Mean	three	0.884	43.67	8.61	14.70	3.41
	five	0.884	44.42	8.77	14.68	3.37
Total mean		0.884	44.04	8.69	14.69	3.39
$LSD_{0.05}$						
Kind of calcium fertilizer (A)		n.s.	0.701	n.s.	0.183	0.113
Number of treatments (B)		n.s.	0.374	0.102	n.s.	n.s.
Interaction (A × B)		n.s.	1.182	n.s.	0.308	0.191

The Mn content in pepper fruits of cv. Caryca F_1 ranged between 8.53 and 8.81 mg Mn kg^{-1} d.m. Statistically, no influence of the type of Ca preparation on the Mn content in sweet pepper was recorded. What draws attention, however, is a higher content of this microelement in fruits of plants treated 5 times with calcium as compared to objects which had only 3 treatments. Similar Mn content in pepper fruits was recorded also by other authors, e.g. Casado-Vela et al. (2007) – approx. 7 mg kg^{-1} d.m., Martinez et al. (2008) – 9.5 mg kg^{-1} d.m. Considerably higher Mn content in peper fruits was determined by Jadczak, Grzeszczuk (2004) – 15 mg kg^{-1} d.m., Bernardo et al. (2008) – 25-29 mg kg^{-1} d.m., Paradiković et al. (2013) – 18 mg kg^{-1} d.m., whereas a much lower level was found by Kmiecik, Lisiewska (1994) – 1.4-1.6 mg kg^{-1} d.m. and Rubio et al. (2002) – 0.7 mg kg^{-1} d.m.

The Zn content in fruit of cv. Caryca F_1 ranged between 14.39 and 15.03 mg Zn kg^{-1} d.m.). It was proven that feeding sweet pepper plants with calcium had positive influence on the Zn accumulation in fruits. Significantly more zinc was recorded in fruits of plants fed with the examined calcium preparations (average 14.61-14.83 mg Zn kg^{-1} d.m.) compared to the control (average 14.43 mg Zn kg^{-1} d.m.). The number of treatments did not differentiate the Zn content in pepper fruits. Other authors recorded similar Zn content in pepper: Casado-Vela et al. (2007) – 10 mg kg^{-1} d.m., Martinez et al. (2008) – 15.6 mg kg^{-1} d.m., Jadczak et al. (2010) – 12.3 mg kg^{-1} d.m., Paradiković et al. (2013) – 10-15 mg kg^{-1} d.m., Zaki et al. (2013) – 14.7-18.7 mg kg^{-1} d.m. However, higher content was reported elsewhere: Jadczak et al. (2004) – 32.75 mg kg^{-1} d.m., Bernardo et al. (2008) – 26-30 mg kg^{-1} d.m. The Zn content reported Kmiecik, Lisiewska (1994) – 2.3-2.7 mg kg^{-1} d.m., and Rubio et al. (2002) – 1.7 mg kg^{-1} d.m. was several-fold lower.

The Cu content in fruit of cv. Caryca F_1 ranged from 3.12 to 3.83 mg Cu kg^{-1} d.m. The foliar feeding of sweet pepper cultivated in field with calcium had a positive effect on the accumulation of this micronutrient in fruits. The significantly highest Cu was contained in fruits obtained from fed plants – $Ca(NO_3)_2$, mean 3.73 mg Cu kg^{-1} d.m., compared to the other objects and the control (mean 3.12-3.38 mg Cu kg^{-1} d.m.). A relationship was verified between the type of Ca preparation and the number of applied treatments. After the application of calcium nitrogen, more Cu was contained in fruits of plants which were treated 5 times. Regarding Librel Ca, the number of treaments did not significantly differentiate the Cu content, although 5 foliar feeding treatments with Insol Ca led to a decrease of the content of this microelement in sweet pepper fruits. Noteworthy is the fact that the Cu content in pepper described in this study is comparable only with the data published by Casado-Vela et al. (2007) – 5 mg kg^{-1} d.m. and Perez-Lopez et al. (2007) – 0.22 mg kg^{-1} f.m., while Kmiecik, Lisiewska (1994) – 0.8-1.1 mg kg^{-1} d.m and Rubio et al. (2002) – 0.7 mg kg^{-1} d.m. presented lower values. Our results, however, are lower than determined by Jadczak, Grzeszczuk (2004) – 10.67 mg kg^{-1} d.m., Bernardo et al. (2008) – 7.7-8.6 mg kg^{-1} d.m., Martinez et al. (2008) – 6.9 mg kg^{-1} d.m., Zaki et al. (2013) – 5.6-15.6 mg kg^{-1} d.m.

CONCLUSIONS

1. Foliar feeding with calcium did not have significant influence on the dry matter content (%) in fruits of cv. Caryca F_1 sweet pepper plants grown in a field.

2. The applied calcium preparations significantly diversified the content of total nitrogen, phosphorus, calcium, iron, zinc and copper in pepper fruits. After the application of calcium nitrate, a higher content of potassium, zinc and copper was recorded; the application of Insol Ca enhanced the potassium and copper content, while feeding with Librel Ca raised the content of potas-

sium, iron, zinc and copper, and the content of phosphorus was lower after the application of Insol Ca and Librel Ca, all compared to the control.

3. The different number of treatments did not significantly influence the chemical composition of pepper fruits except the iron and manganese content. 5 treatments increased the iron and manganese content in fruits.

4. Compared to the control, the applied calcium preparations and the number of treatments on calcium accumulation had positive influence on calcium accumulation in pepper fruits (more Ca by 25.3% for 5 and 15.3% for 3 treatments, on average). The highest calcium content was observed after the application of calcium nitrate, and 5 treatments increased the calcium content in fruits, as well.

REFERENCES

Aleksander S.E., Clough G.H. 1998. *Spunbonded rowcover and calcium fertilization improve quality and yield in bell pepper*. Hort. Sci., 33(7): 1150-1152.

Bernardo A., Martínez S., Alvarez M., Fernández A., López M. 2008. *The composition of two Spanish varietes (Frenso de la Vega and Benavente-Los Valles) in different ripening stages*. J. Food Quality, 31: 701-716.

Berova M., Pevicharova G., Stoeva N., Zlatev Z., Karanatsidis G. 2013. *Vermicompost affects growth, nitrogrn content, leaf gas exchange and productivity of pepper plants*. J. Elem. 18(4): 565-576. DOI: 10.5601/jelem. 2013.18.4.393

Bubicz M., Perucka I, Materska M. 1999. *Content of bioelements of hot and sweet pepper fruit* (*Capsicum annuum* L.). Biul. Magnezol., 4(2): 289-292.

Buczkowska H., Michałojć Z. 2012. *Comparison of qualitative traits, biological value, chemical compounds of sweet pepper fruit*. J. Elem.,17(3): 367-377.

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

Casado-Vela J., Sellés S., Díaz-Crespo C., Navarro-Pedreño J., Mataix-Benyto J., Gómez I. 2007. *Effect of composted sewage sludge application to soil on sweet pepper crop* (*Capsicum annuum* var. annuum) *grown under two exploitation regimes*. Waste Manage., 27: 1509-1518.

Gajc-Wolska J., Skąpski H. 2002. *Yield of field grown sweet pepper depending on cultivars and growing conditions*. Fol. Hort., 14(1): 95-103.

Gajc-Wolska J., Zielony T., Radzanowska J. 2005. *Evaluation of yield and fruit quality of new hybrids of sweet pepper* (*Capsicum annuum* L.). Zesz. Nauk. AR we Wrocławiu 515, Rol., 86: 139-147. (in Polish)

Ghoname A.A., Mona G.D., Riad G.S., El-Tohamy W.A. 2009. *Effect of nitrogen and biostimulants foliar application on the growth,yield and chemical composition of hot pepper grown under sandy soil conditions*. Res. J. Agric. Biol. Sci., 5(5): 840-852.

Golcz A. 2001. *Effects of diversified pepper fertilisation with potassium*. Zesz. Nauk. ATR w Bydgoszczy, 234, Rolnictwo 46: 53-59. (in Polish)

Golcz A., Kujawski P. 2004. *Evaluation of the biological value of the fruit of several hot pepper* (*Capsicum annuum* L.) *cultivars*. Rocz. AR w Poznaniu 360, Ogrodnictwo, 38: 37-42.

Golcz A., Kujawski P., Potylicka B. 2004*a*. *The influence of the type of fertilizer potassium on yielding hot pepper (Capsicum annuum* L.*)*. Fol. Univ. Agric. Stetin., Agric., 239(95): 109-114. (in Polish)

Golcz A., Kujawski P., Zimowska H. 2004b *Effect of potassium fertilizer type on the content of nutritive components in leaves and fruits of hot pepper (Capsicum annuum* L.*)*. Rocz. AR w Poznaniu 356, Ogrodnictwo, 37: 75-80.

Guil-Guerrero J.L., Martínez-Guirado C., del Mar Rebolloso-Fuentes M., Carrique-Pérez A. 2006. *Nutrient composition and antioxidant activity of 10 pepper (Capsicum annuum) varieties*. Eur. Food Res. Technol., 224: 1-9.

Jadczak P., Grzeszczuk M. 2004. *Content of mineral compounds in fruit some cultivars of hot and sweet pepper (Capsicum annuum* L.*)*. J. Elementol., 9(1): 15-23.

Jadczak P., Grzeszczuk M., Kosecka D. 2010. *Quality characteristics and content of mineral components in fruit of some cultivars of sweet pepper (Capsicum annuum* L.*)*. J. Elementol., 15(3): 509-515.

Kmiecik W., Lisiewska Z. 1994. *Evaluation of eight sweet pepper cultivars for field growing in the Kraków region from the aspect of requirements of the canning industry*. Fol. Hortic., 6(2): 35-43.

Kowalska I., Sady W. 2012. *Effect of nitrogen form, type of polyethylene film covering the tunnel and stage of fruit development on calcium content in sweet pepper fruits*. Acta Sci. Pol., Hort. Cul., 11(3): 91-100.

Marcelis L.F.M., Ho L.C. 1999. *Biossom-end rot in relation to growth rate and calcium content in fruits of sweet pepper (Capsicum annuum* L.*)*. J. Exp. Bot., 50(332): 357-363.

Marín A., Rubio J.S. Martinez V., Gil M. 2009. *Antioxidant compounds in green and red peppers as affected by irrigation frequency, salinity and nutrient solution composition*. J. Sci. Food Agric., 89: 1352-1359.

Martínez S., Curros A., Bermúndez J., Carballo J., Franco I. 2007. *The composition of Arnoia peppers (Capsicum annuum* L.*) at different stages of maturity*. Int. J. Food Sci. Nutr., 58(2): 150-161.

Medina-Lara F., Echevarría-Machado I., Pacheco-Arjona R., Ruiz-Lau N., Guzmán-Antonio A., Martinez-Estevaz M. 2008. *Influence of nitrogrn and potassium fertilization on fruiting and capsaicin content in habanero pepper (Capsicum chinense* Jacq.*)*. Hort. Sci., 43(5): 1549-1554.

Michalik Ł. 2000. *Content of some mineral constituents in sweet pepper fruits*. Ann. UMCS, Sect. EEE, supl, 8: 379-381. (in Polish)

Michałojć Z., Dzida K. 2012. *Yielding and biological value of sweet pepper fruits depending on foliar feeding using calcium*. Acta Sci. Pol. Hort. Cult., 11(3): 255-264.

Michałojć Z., Horodko K. 2006. *Effect of calcium foliar nutrition on yield and chemical composition of sweet pepper*. Acta Agroph., 7(3): 671-679. (in Polish)

Paradiković N., Vinkovic T., Vinković Vrček I., Tkalec M. 2013. *Natural biostimulants reduce the incidence of BER in sweet yellow pepper plants (Capsicum annuum* L*)*. Agric.Food Sci., 22(2): 307-317.

Pérez-López A.J., López-Nicolas J.M., Núñez_Delicado E., del Amor F., Carbonell_-Barrachina Á.A. 2007. *Effects of agricultural practices on color, carotenoids composition, and minerals contents of sweet peppers, cv. Almuden*. J. Agric. Food Chem., 55: 8158-8164.

Pokluda R. 2004. *Content of selected nutritional element in fruits of several pepper cultivars*. Ann. UMCS, Sect. EEE, 14: 37-43.

Rubio C., Hardisson A., Martín R.E., Báez A., Martín M.M. 2002. *Mineral composition of the red and green pepper (Capsicum annuum) from Tenerife Island*. Eur. Food Res. Technol., 214: 501-504.

Zaki N., Hakmaoui A., Ouatmane A., Fernandez-Trujillo J.P. 2013. *Quality characteristics of Moroccan sweet paprika (Capsicum annuum* L.*) at different sampling times*. Food Sci. Technol. (Campinas), 33(3): 577-585.