Turkish Journal of Agriculture and Forestry

http://journals.tubitak.gov.tr/agriculture/

Research Article

Turk J Agric For
(2016) 40: 222-228
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doi:10.3906/tar-1501-56

Yield and fruit quality of sweet pepper depending on foliar application of calcium

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Received: 14.01.2015 • **Accepted/Published Online:** 17.10.2015 • **Final Version:** 05.02.2016

Abstract: The proper feeding of field plants is one of the most significant factors with an impact on their growth and development. Calcium is one of the basic nutrients of plants, crucial in many cell processes. Calcium in a plant is reutilized very poorly, and hence symptoms of deficiency of this component are observed on the youngest leaves, apexes of stems and roots, and, most importantly, on the fruits. The aim of this study was to evaluate the effects of foliar Ca feeding on the yield of sweet pepper 'Caryca F_1' and on selected elements of its fruit quality in field ground cultivation. Ca was applied in the form of the following preparations: $Ca(NO_3)_2$, Insol Ca, or Librel Ca. Calcium preparations were applied on 3 or 5 dates in 1% concentration of the solution to the full wetting of the plants. A positive influence of Ca feeding on the marketable yield of the fruit was observed: 4.26–4.63 kg m^{-2} as compared with the controls at 3.80 kg m^{-2}. Calcium foliar feeding caused a limited number of fruits with BER symptoms at 4.3%–5.2% of the total number of fruits, as compared with 14.4% of those of the control fruits. The use of $Ca(NO_3)_2$ had a positive effect on the accumulation of vitamin C and carotenoids as compared with other fertilizers. Reduced Ca spraying proved to be beneficial in terms of fruit yield and concentrations of carotenoids.

Key words: Vegetables, *Capsicum annuum* L., calcium preparations, blossom-end rot, L-ascorbic acid

1. Introduction

Vegetables, which provide essential nutrients and health-promoting elements, constantly remain in the area of interest of producers and consumers of so-called "healthy foods". The selection of vegetables cultivated for harvest of fresh material is very wide, and the diversity of products and biological components allows for great potentials of dietary compositions. Pepper (*Capsicum* sp.) is cultivated in many countries around the world as a precious vegetable with high biological value (Molnár et al., 2005; Wetwitayaklung and Phaechamud, 2011). The field cultivation of sweet pepper for fresh vegetable marketing as well as for processing has gained significant economic importance in Poland in recent years (Gajc-Wolska and Skąpski, 2002; Buczkowska, 2007; Gajc-Wolska et al., 2007). The unique taste quality and health-promoting properties of the fruit, conditioned by the presence of antioxidants and mineral components, contribute to the value of this vegetable in the human diet (Flores et al., 2004; Pokluda, 2004; Zaki et al., 2013).

Obtaining a good marketable yield of sweet peppers from open field cultivation in less favorable conditions depends to a large extent on the choice of cultivar and on the application of treatments that enhance the yield (Buczkowska, 2007; Gajc-Wolska et al., 2007), including mineral feeding of plants and the level of feeding (Marín et al., 2009; Kowalska and Sady, 2012; Michałojć and Dzida, 2012). Proper mineral feeding of plants plays an important role in shaping their growth and development, as well as their size and quality of yield. In recent years, calcium has become more popular as its additional function of a secondary information transmitter was discovered. Calcium ion uptake by plants is to a large extent genetically conditioned. The process of Ca absorption, transport, and distribution in a plant is influenced by many soil, biological, and climatic factors (White and Broadley, 2003; Bouzo and Cortez, 2012; Shakoor and Bhat, 2014). Low Ca concentration in plant tissues is the main cause of various physiological disorders. One of the most frequently appearing disorders in pepper feeding in covered cultivation as well as in open fields, which happens in the period of most intense fruit growth, is blossom-end rot (BER), which destroys the usefulness of pepper, tomato, and eggplant fruits (Alexander and

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Clough, 1998; Paradiković et al., 2004, 2013; Kowalska and Sady, 2012; Michałojć and Dzida, 2012). The main cause of this disorder is limited water absorption by plants, which is closely related to Ca transport (Morard et al., 2000; Suzuki et al., 2003; Cobanero et al., 2004). One of the ways to prevent BER occurrence is spraying with Ca foliar preparations. Preharvest and postharvest application of calcium salts is an effective treatment in the control of physiological disorders and in the reduction of fungi pathogen incidence. A quick and effective way to limit the occurrence of Ca deficiency symptoms in a plant is to deliver that component directly in the form of spraying those parts of the plants where its transfer is limited (leaves, fruits) (Casado-Vela et al., 2007; Kowalska and Sady, 2012; Michałojć and Dzida, 2012). Calcium foliar feeding significantly lowered the BER occurrence on the fruits of tomato (Rab and Haq, 2012; Kazemi, 2014), and at the same time had positive effects on the biological value of the yield. A combination of standard fertilization and foliar feeding with 0.5% solution of Ca in the cultivation of peppers in greenhouses completely eliminated BER (Paradiković et al., 2004). It needs to be mentioned that an increased quantity of Ca in the root environment can lead to an increased content of nutrients (lycopene, β-carotene) and to antioxidant activities in pepper (Flores et al., 2004). The premise of the current study was to compare the effects of calcium nitrate and two fertilizers containing calcium in terms of a good calcium supply of plants. Due to the large amount of labor incurred in the performance of treatments in sweet pepper field cultivation, the same number of treatments within each formulation was used. The amount of calcium delivered to plants was varied with the type of fertilizer (19% Ca, 9.9% Ca, and 9.5% Ca), and the number of sprayings (3 or 5 times). As a source of calcium we used calcium nitrate, a fertilizer commonly used in horticultural production, and two other fertilizers with high calcium contents. The study determined the total and marketable yield, the total number of fruits, the numbers of marketable fruits and fruits with BER, and the content of dry matter, L-ascorbic acid, carotenoids, and sugars of sweet pepper in field cultivation.

2. Materials and methods

The present study on sweet pepper 'Caryca F_1' (breeder and distributor: "PlantiCo–Hodowla i Nasiennictwo Ogrodnicze Zielonki") was carried out in 2010–2012 on a private farm in Zezulin (51.35°N, 22.85°E), near Lublin, on gray-brown podsolic soil from loess material on chalk marls, with 1.8% of organic matter in a layer of arable land. Winter wheat was used as a forecrop every year of the experiment. Every year in autumn, organic fertilization was applied with manure (30 t ha^{-1}). The content of mineral components in the soil varied in the following ranges: 30–39 mg dm^{-3} N-NO_3, 160–180 mg dm^{-3} P, 130–180 mg dm^{-3} K, 2000–2300 mg dm^{-3} Ca, and 40–75 mg dm^{-3} Mg, at pH_{H2O} varying between 6.5 and 6.8. Prior to seedling planting, mineral fertilization was applied with nitrogen in the quantities of 50 kg ha^{-1} in 2010, 60 kg ha^{-1} in 2011, and 75 kg ha^{-1} in 2012. The amount of nitrogen was determined based on chemical analysis of the soil carried out in each year of the study. Top-dressing fertilization was applied twice in the form of concentrated liquid multicomponent fertilizer Florowit (0.5%). The fertilizer content was as follows: N-total was 3.0%, (N–nitrate (0.7%) and N–amide (2.3%)), water soluble K_2O was 2.0%, Cu was 70 mg dm^{-3}, Fe was 400 mg dm^{-3}, Mn was 170 mg dm^{-3}, Mo was 20 mg dm^{-3}, and Zn was 150 mg dm^{-3}. The sweet pepper plantation was not irrigated. The pot seedlings of pepper were set into the field in the last 10 days of May (4.20 pieces per m^2). The experiment was established as a two-factor experiment, in a randomized system, in 4 repetitions. The surface of each replication field equaled 9.4 m^2, and 40 plants were cultivated in each field. The study examined the effect of two factors: 1) the type of calcium preparation ($Ca(NO_3)_2$ (19% Ca; 15.5% N); Insol Ca (9.9% Ca; 1.2% Mg; 0.1% Mn; 0.02% B; 0.02% Zn; 0.01% Cu, Cu, Mn, and Zn as chelated EDTA); or Librel Ca (9.5% Ca as chelated EDTA)) in reference to the control (spraying with water); and 2) the number of treatments: 3 or 5. The examined mixtures were applied in concentration of 1% until total wetting of the plants. Plants received the same amount of mixture, but with different calcium contents. The feeding of sweet pepper plants began when the first fruits reached a diameter of 1–2 cm (in the first 10 days of July). The schedule of the more important cultivation activities and applied treatments of extraradical feeding is presented in Table 1. The fruits of pepper were collected gradually, at the full maturity phase, and separately from each replication field. We estimated the total yield, the marketable yield, the total number of fruits, the number of marketable fruits (healthy fruits of typical size for the variety, weighing >80 g), and the number of unmarketable fruits with a determination of the number of fruits with symptoms of BER. After the completion of the study, the following parameters were determined: the total and marketable yields of the fruits (kg m^{-2}), the total number of fruits, the number of marketable fruits, and the number of fruits with symptoms of BER (pcs m^{-2}). Fruit samples were collected at random from every combination in mid-September (full fruiting) for chemical analysis. The share of dry matter in fresh fruits was determined by drying at 105 °C. The content of L-ascorbic acid was determined by the Tillmans method. The sums of carotenoids after extraction with oil ether were determined by a spectrophotometric analysis at a wavelength of 450 nm (Shaha et al., 2013). The total sugars and reducing sugars were determined by the Luff-Schoorl method. Tests were performed in 3 repetitions.

Table 1. Schedule of cultivation of sweet pepper in 2010–2012.

Year	Sowing seeds	Planting seedlings	Term of application								The beginning	The end
			Three times			Five times						
			1	2	3	1	2	3	4	5	of the harvest	
2010	29.03	25.05	02.07	24.07	15.08	02.07	13.07	24.07	3.08	14.08	25.08	06.10
2011	28.03	28.05	05.07	26.07	18.08	05.07	16.07	26.07	7.08	18.08	29.08	04.10
2012	30.03	31.05	06.07	27.07	19.08	06.07	17.07	27.07	8.08	19.08	27.08	02.10

Since the results obtained in the different years of research were comparable, they were recorded as mean values of a 3-year study. Results were processed statistically with ANOVA. The significance of the differences was evaluated using the Tukey multiple confidence intervals at $\alpha = 0.05$.

3. Results and discussion

The examined pepper plants were characterized by correct growth and development. No visible symptoms of nutrients deficiency or toxic symptoms were observed. On average, significantly greater total and marketable yields of fruits were collected from fruits treated with calcium than from fruits not treated with calcium (Table 2). The excess of the total yield under calcium application was 2.8%–8.6%, whereas that of the marketable yield was between 12.1% and 21.8%, as compared with the total yield (4.99 kg m^{-2}) and the marketable yield (3.80 kg m^{-2}) obtained from control plants. This conflicts with results reported in a study by Alexander and Clough (1998) and may be related to the additional effect of genetic (cultivar) and environmental (cultivation place) components. Similarly, data provided by Flores et al. (2004) indicate that the application of calcium to the root environment did not cause significant changes in fresh or dry matter of pepper fruits. On the other hand, another study reported that the additional application of calcium in the field cultivation of pepper had positive effects on the fresh matter of fruits and on the total yield (El-Tohamy et al., 2006). These differences might result from the way of calcium application as well as from the environmental conditions of cultivation. Calcium translocation is very difficult to achieve due to the limited absorption and penetration of Ca ions in fruits and its movement in fruit tissue. Ca foliar feeding might not be effective in terms of fresh matter of fruits and soluble solid contents, whereas the effect of calcium application can vary in different cultivation regions (Bouzo and Cortez, 2012). Greater total and marketable yields were observed in objects that had 3 treatments of calcium preparation as compared with those that had 5 treatments (Table 2). It can be noted that in calcium treated objects the share of marketable yield of fruits in the total yield was greater than that of the control objects. Insol Ca treatment had 83.0% marketable yield, Librel Ca had 84.3%, and calcium nitrate had 85.6%, while the control objects had 76.1% marketable yield (Table 2). The marketable yield of 'Caryca F_1' fruits was comparable to the results of other studies conducted in this region (Buczkowska, 2007; Rożek et al., 2012), as well as in other regions of Poland (Gajc-Wolska and Skąpski, 2002; Gajc-Wolska et al., 2007; Szafirowska and Elkner, 2008). This indicates the great uniformity of hybrid pepper cultivars in terms of size and quality of yield as well as a good adaptation of the examined cultivars to changing climate conditions. The results concerning the total number of fruits and the number of marketable fruits from 1 m^2 indicate a significant influence of the examined components on the yield parameters (Table 3). Greater numbers of both total and marketable fruits were obtained from objects on which foliar application of calcium preparation was applied. However, no explicit influence of the quantity and the number of calcium foliar treatments on the number of fruits was noted. Research conducted on tomatoes (Rab and Haq, 2012; Kazemi, 2014) indicates that Ca application significantly increased the number of fruits from a plant. It seems that this was above all related to the positive effect of calcium on the limitation of the fruit bud falling process. The share of the number of marketable fruits in the total number of fruits in objects with Ca spraying ranged between 65.8% and 73.0%, whereas in the control objects it was 64.8% (Table 4). A limiting influence of calcium foliar feeding on the number of fruits with symptoms of BER was noted (Tables 2 and 3). An average of 7.1 fruits from 1 m^2 with BER were collected in the control objects, whereas their number on plants treated with calcium ranged between 2.3 and 2.7 pcs m^{-2}. The positive effect of Ca application on the reduced incidence of BER on pepper fruits was confirmed in the share of the number of these fruits in the total number of fruits, which depended on the type of applied calcium preparation, as follows: with Librel Ca they were 4.2%, with Insol Ca 4.3%, and with calcium nitrate 5.2%, whereas in the control objects they were 14.4% (Table 3). However, no explicit influence of the number of calcium

Table 2. Total and marketable yield of sweet peppers (mean for 2010–2012).

Kind of calcium fertilizer	Total yield (kg m^{-2})			Marketable yield (kg m^{-2})			Share of the marketable yield in the total yield (%)		
	A*	B	mean	A	B	mean	A	B	mean
$Ca(NO_3)_2$	5.62	5.19	5.41	4.85	4.42	4.63	86.3	85.2	85.6
Insol Ca	5.35	4.90	5.13	4.51	4.01	4.26	84.3	81.8	83.0
Librel Ca	5.63	5.21	5.42	4.78	4.36	4.57	84.9	83.7	84.3
Control	5.10	4.88	4.99	3.81	3.78	3.80	74.7	77.4	76.1
Mean	5.43	5.04		4.49	4.14		82.7	82.1	
$LSD_{0.05}$ Kind of calcium fertilizer Number of treatments Interaction			 0.236 0.126 0.396			 0.202 0.108 0.339			

*Number of treatments: A – three; B – five.

Table 3. Structure of the number of sweet pepper fruits (No m^{-2}) (mean for 2010–2012).

Kind of calcium fertilizer	Total fruits			Marketable fruits			Fruits with BER*		
	A**	B	mean	A	B	mean	A	B	mean
$Ca(NO_3)_2$	50.1	52.0	51.1	37.6	36.9	37.3	2.6	2.7	2.7
Insol Ca	54.0	52.1	53.1	36.5	33.4	34.9	2.1	2.4	2.6
Librel Ca	59.1	52.4	55.7	40.4	36.2	38.3	2.6	2.1	2.4
Control	49.8	49.3	49.6	32.0	32.2	32.1	6.8	7.4	7.1
Mean	53.2	51.5		36.9	34.7		3.6	3.7	
$LSD_{0.05}$ Kind of calcium fertilizer Number of treatments Interaction			 2.39 1.28 4.01			 1.79 0.96 3.04			 0.81 n. s.*** 1.37

BER*–Blossom-end rot; **Number of treatments: A – three; B – five; *** not statistically significant differences.

foliar treatments on the incidence reduction in BER symptoms was noted. Foliar feeding with calcium led to a reduced number of fruits with BER symptoms in the cultivation of sweet pepper in a greenhouse (Michałojć and Dzida, 2012; Paradković et al., 2012). Similarly, in the field cultivation of tomato, the exogenic application of Ca significantly contributed to an increase in plant height and the number and firmness of fruits, as well as to a decrease in BER incidence (Rab and Haq, 2012; Kazemi, 2014). In the field cultivation of pepper, however, until now a reduction in the symptoms of BER with the application of calcium nitrate (through a drip watering system) could not be achieved; only an increase in the yield of fruits of the highest quality was reported (Alexander and Clough, 1998). The susceptibility of sweet pepper to BER might be genetically determined. In a study by Marcelius and Ho (1999) the share of the number of fruits with BER symptoms depended on the cultivar and ranged between 10% and 40%.

The fruit quality of sweet pepper was evaluated at full bearing based on the share of dry matter of fruits and the content of total sugars, reducing sugars, L-ascorbic acid, and carotenoids. The share of dry matter in fruits reached an average of 7.12% (Table 4) and was not significantly dependent on the number of treatments. Significantly less dry matter was recorded in fruits of plants sprayed with calcium (6.98%–7.07%) as compared with the controls (7.36%). The examined pepper fruits contained less

Table 4. Share of the number of marketable fruits and the number of fruits with BER* in the total number of fruits of sweet peppers (%) (mean for 2010–2012).

Kind of calcium fertilizer	Marketable fruits			Fruits with BER*		
	A	B	mean	A	B	mean
$Ca(NO_3)_2$	75.0	71.0	73.0	5.2	5.2	5.2
Insol Ca	67.6	64.1	65.8	3.9	4.6	4.3
Librel Ca	68.4	69.1	68.9	4.4	4.0	4.2
Control	64.3	65.3	64.8	13.7	15.0	14.4
Mean	69.4	67.4		6.8	7.2	

*The explanation is the same as in Table 3.

dry matter than those evaluated in other studies (Gajc-Wolska et al., 2007; Kowalska and Sady, 2012; Michałojć and Dzida, 2012). Vegetables are generally characterized by quite large fluctuations in the content of water or dry matter, which are related to various factors. Dry matter accumulation by pepper plants is slow at the initial growth stage, but increases at the beginning of fruit bearing (Marcussi et al., 2004). Dry matter content in pepper fruits can be differentiated not only by ontogenetic and genetic factors (Niklis et al., 2002), but also by agricultural factors (Yang et al., 2012). Pepper is a good source of reducing sugars, mainly glucose and fructose. It seems that the concentration of the abovementioned components is not modified by the levels of calcium, potassium, or nitrogen (Flores et al., 2004). On the other hand, the content of total sugars and reducing sugars in pepper fruits increased as an effect of treating the plants with Wapnowit (Michałojć and Dzida, 2012). In the present research, the content of total sugars in fruits from objects treated with calcium (3.83%–3.90%) was significantly lower in comparison with fruits from the control plants (4.14%), which may indicate the limiting effect of the examined calcium preparations on the accumulation of these components (Table 4). Yet, the content of reducing sugars did not depend on the examined factors and ranged between 3.37% and 3.51%. The contents of total sugars and reducing sugars determined in the studied fruits were lower as compared with results from earlier studies (Pokluda, 2004; Gajc-Wolska et al., 2007; Buczkowska and Michałojć, 2012; Michałojć and Dzida, 2012), indicating the presence of effects other than genetic factors of variation. The above data indicate a high changeability of the chemical contents of sweet pepper fruits with a certain modifying influence of foliar application of calcium.

The quality of pepper fruits is related mainly to the content of L-ascorbic acid and carotenoids. L-ascorbic acid is one of the most important nutrients of pepper due to its wide biological activity in the human body (Iqbal et al., 2004; Hacişevki, 2009). In a study reported by Kim et al. (2011) it was indicated that the contents of capsanthin and L-ascorbic acid in fruits of pepper correlated well with pepper's antioxidant activity. L-ascorbic acid content in fruits of 'Caryca F_1' varied widely and ranged between 144.8 and 227.0 mg 100 g^{-1} FM (Table 4). A similar content of L-ascorbic acid was presented in other studies as well (Lee and Kader, 2000; Zaki et al., 2013), which confirms the high stability in accumulation of this important element in pepper fruits. Some papers have reported calcium's stimulating influence on the concentration of L-ascorbic acid (Michałojć and Dzida, 2012; Kazemi, 2014), but Flores et al. (2004) did not confirm such dependence. The present study did not show a clear and stimulating effect of the calcium preparations and the number of treatments on the accumulation of this compound. Fruits obtained from plants treated with Insol Ca contained significantly less L-ascorbic acid as compared with fruits from plants treated with calcium nitrate (203.0 mg 100 g^{-1} FM) and with the controls (202.1 mg 100 g^{-1} FM). Moreover, it was noted that 5 calcium treatments in the form of calcium nitrate and Librel Ca had a positive effect on L-ascorbic acid in pepper fruits. The increase was about 27% in comparison with fruits collected from the control plants and those treated with Insol Ca. Pepper fruits are a valuable source of carotenoids, which possess antioxidant and antiphlogistic activity (Molnár et al., 2005; Kim et al., 2010). The content of total carotenoids in the examined samples remained in the range of 0.990 to 1.562 mg in 100 g of fresh matter (Table 5). The control fruits contained significantly more carotenoids than the fruits of plants treated with Insol Ca and Librel Ca. No significant differences were noted between the content of carotenoids in the control fruits and that in fruits collected from plants treated with $Ca(NO_3)_2$.

Table 5. The content of selected components of nutritive value of sweet pepper (mean for 2010–2012).

Kind of calcium fertilizer	Dry matter (%)			Total sugars (% FM)			Reducing sugars (% FM)			Vitamin C (mg 100^{-1} g FM)			Carotenoids (mg 100^{-1} g FM)		
	A	B	mean	A	B	mean	A	B	mean	A	B	mean	A	B	mean
Ca $(NO_3)_2$	7.00	6.96	6.98	3.94	3.74	3.83	4.85	3.73	3.29	179.0	227.0	203.0	1.562	1.386	1.474
Insol Ca	7.14	6.98	7.06	4.05	3.75	3.90	4.51	3.35	3.60	161.5	164.5	163.0	1.272	1.168	1.220
Librel Ca	6.94	7.19	7.07	3.82	3.84	3.83	4.78	3.42	3.33	144.8	184.2	164.5	1.032	0.990	1.011
Control	7.36	7.37	7.36	4.05	4.22	4.14	3.81	3.42	3.48	209.5	194.7	202.1	1.340	1.445	1.392
Mean	7.11	7.13		3.97	3.88		4.49	3.48		173.7	192.6		1.302	1.247	
$LSD_{0.05}$ Kind of calcium fertilizer Number of treatments Interaction			0.167 n. s. 0.281			0.153 n. s. 0.257			n. s. n. s. n. s.			4.51 2.41 7.61			0.0779 0.0416 0.1314

The explanations are the same as in Table 3.

Some previous studies indicated a visible influence of calcium application on the concentration of lycopene and β-carotene in fruits of tomato (Kazemi, 2004) and pepper grown in a greenhouse (Flores et al., 2004). The question of whether or not foliar application of calcium in field-grown peppers can modify the concentrations of particular carotenoids remains open.

To summarize, the calcium foliar feeding of sweet pepper 'Caryca F_1' plants significantly increased the fruit yield in field cultivation and caused a limited number of fruits with symptoms of BER as compared with the controls. Calcium supplementation modified the chemical composition of the fruit. The application of calcium preparations led to reduced dry matter and total sugar content, and, with the exception of calcium nitrate, vitamin C and carotenoids. The number of sprayings did not make a difference in the contents of dry matter, total sugars, or reducing sugars in the studied fruits. Increasing the frequency of treatments resulted in an increase in vitamin C content and a reduction in carotenoid contents in fruits of sweet pepper.

Acknowledgments

The present research was supported by the Ministry of Science and Higher Education of Poland as a part of statutory activities of the Department of Vegetable Crops and Medicinal Plants, University of Life Science in Lublin.

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