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Effect of calcium foliar application on some fruit quality characteristics of 'Sinap Orlovskij' apple

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Abstract. Effect of calcium fertiliser sprays on eight-ten-year-old apple trees of the cv. 'Sinap Orlovskij' on rootstock 62-396 was investigated at the Lithuanian Institute of Horticulture in 2001–2003. Calcium chloride, calcium nitrate, liquid experimental calcium fertilisers and Wuxal Calcium were used. Calcium chloride was applied twice at the time close to harvest (total CaO rate – 5.9 kg ha^{-1}). Other fertilisers were used fivefold from the beginning of June (total CaO rate – 6 kg ha^{-1}) in the combination of two sprays with calcium chloride (CaO rate – 5.9 kg/ha).

The most significant effect of calcium fertilisers on fruit calcium content was found in 2003. When fertilisers were applied sevenfold, fruit calcium increased by 50–120 mg/kg of dry fruit weight in comparison with the control. The most unfavourable for calcium accumulation was the warm and dry weather in year 2002. Apples contained only 170–230 mg of calcium per kg of fruit dry matter and bitter pit affected up to 35% of apples. In years 2001 and 2003 fruit calcium content was 300–330 and 340–460 mg/kg, respectively, bitter pit affected up to 2% of apples.

Sevenfold applied calcium fertilisers decreased bitter pit incidence about twice in comparison with the control and two applications of calcium chloride. All tested fertilisers had a similar effect on bitter pit reduction.

Calcium fertilisers had not a consistent effect on fruit flesh firmness, soluble solids content and natural weight loss.

Key words: bitter pit, calcium, flesh firmness, weight loss, soluble solids

INTRODUCTION

Apple storability and quality in large extent is determined by the genotype of the cultivars. Some other factors may influence expression of this peculiarity. The role of balanced nutrition on fruit storability is well known (Terblanche et al., 1980; Johnson, 1980; Link, 1980; Błaszczyk & Ben, 1996; Dris et al., 1998). Adequate nutrition ensures a balance in fruit mineral composition. Calcium content and its ratio with some other elements (N, K, Mg) are in great concern. When apples accumulate too little of Ca, they are more susceptible to such physiological disorders as bitter pit, internal breakdown, scald (Centkowski & Tomala, 2000; Dris et al., 1998) or even to the rots, caused by pathogens (Biggs et al., 1993). Apples with Ca deficiency ripen earlier (Tomala & Radecka, 1997) and loose more weight during storage (Tabatabaie &

Malakouti, 1998; Saftner et al., 1998). Production of apples characterised by a high Ca content is very important for successful storage and handling. The desirable Ca content may be different for various cultivars. In general, it is reported that a Ca content above 45–60 mg/kg of fresh fruit weight is satisfactory (Dris et al., 1998; Johnson, 1980). As some other elements influence apple quality and storability as well, often attention is paid to the ratio of N/Ca, K/Ca, (K+Mg)/Ca, Mg/Ca etc. K/Ca ratio above 5.8 in T-stage fruitlets is associated with a considerable risk of subsequent bitter pit development (Weibel et al., 2000). When K/Ca ratio in mature 'Jonagold' fruits does not exceed 28, only about 2% of apples may be affected by bitter pit (Piestrzeniewicz & Tomala, 2001).

Calcium accumulation in apples is influenced by different management practices and ecological conditions (Johnson & Johnson, 1980; Tomala, 1999). Excessive rates of nitrogen and potassium fertilisers, incorrect pruning, long term herbicide application, water and temperature stress, to little crop load and other factors may lead to the decrease of fruit calcium content.

Direct application of calcium to the fruit is the most effective method for increasing fruit calcium content (Conway et al., 2002). The best way is to spray trees with calcium fertilisers. Many calcium fertilisers are proposed to fruit growers. Experimental results indicate different effects of applying calcium fertilisers (Tomala, 1997; Wójcik & Szwonek, 2002; Yuri et al., 2002).

With the introduction of new dwarfing rootstocks and some new cultivars, bitter pit has become a serious problem in Lithuania. Up to now, the most popular calcium fertilisers were calcium nitrate and calcium chloride. They were applied usually 2–3 times close to harvest. The recent experience shows that more frequent application gives better results. The objective of our research was to evaluate effects of application of some calcium fertilisers on apple quality of the cv. 'Sinap Orlovskij'. In Lithuania 'Sinap Orlovskij' is a commercially perspective apple cultivar with a limitation – high susceptibility to bitter pit.

MATERIALS AND METHODS

The experiment was carried out at the Lithuanian Institute of Horticulture in the years 2001–2003. Eight-ten-year-old apple trees of the cv. 'Sinap Orlovskij' on rootstock 62-396 were sprayed either with the calcium chloride, calcium nitrate, liquid experimental calcium fertilisers or Wuxal Calcium. Calcium nitrate used for sprays contained 26.5% of CaO and 15.5% of N. Experimental calcium fertilisers were based on liquid calcium nitrate (14% CaO) with the trace of magnesium nitrate (0.5% MgO); content of nitrogen was 7%. Wuxall Calcium contains 15% of CaO, 2% of MgO, 10% of N and microelements B, Cu, Fe, Mn, Mo. Calcium chloride contained 78% of anhydrous $CaCl_2$.

Calcium chloride was applied twice close to the harvest at a total rate of 5.9 kg ha^{-1} CaO. Other fertilisers were applied in five consecutive sprays (total amount of CaO for all sprays 6 kg/ha) in combination with two applications of calcium chloride (5.9 kg ha^{-1} CaO). The first spray was done in the middle of June, the rest – at two-week intervals. 800 l/ha of water was used for spraying.

The experiment was designed in four randomised blocks. There were 4 apple trees in each experimental plot. The annual yield was 25–30 t $ha.^{-1}$.

Table 1. Average air temperature and rainfall in the period of June–September.

Year	Air temperature (ºC)	Rainfall (mm)
2001	16.4	319
2002	17.7	203
2003	16.3	257
Perennial average	15.3	283

The soil in the experimental orchard was Epicalcari-Endohypogleic Cambisol, clay loam rich in phosphorus and potassium, containing 2.3% of humus and pH_{Kl} 7.2. Moderate rates of nitrogen fertilisers (50–70 kg ha^{-1} N) were applied to herbicide strips every spring.

Meteorological conditions during the fruit growth period in the years 2001–2003 were different (Table 1). The season of 2002 was characterised by high average temperature (17.7ºC) and low rainfall (203 mm).

During these studies, the following measurements in fruit were performed: calcium and potassium content (at harvest), flesh firmness, soluble solids (at harvest and after storage), natural weight loss, bitter pit incidence and intensity (after storage). Fruit calcium and potassium content (mg kg^{-1} in dry weight) was measured with an emission spectrograph; flesh firmness (kG) – with a penetrometer, soluble solids (%) – with a refractometer, natural weight loss (%) – by weighing. In each analysis, a sample of 10 apples was studied. Samples of 100 fruits for bitter pit control were taken from each experimental plot. Incidence of bitter pit in apples was expressed in percents. Bitter pit intensity was evaluated on a 1–10 score scale (1 – small sparse pits, 10 – abundant pits on the entire apple).

Fruits were picked at the end of September and stored until the end of February in a cool storage at the temperature 2–4ºC and relative air humidity 90–95%.

Experimental data were subjected to an analysis of variance. For mean separation, a Duncan's test at $P = 0.05$ was used. The data were analysed by the ANOVA statistical program.

RESULTS AND DISCUSSION

There were not found any differences in the content of calcium among treatments in 2001 (Table 2). In 2002 the highest fruit calcium content was when experimental fertilisers with calcium chloride were applied (270 mg kg^{-1}). Fertilisers significantly increased apple calcium content in 2003, except $CaCl_2$ x 2. The highest increase in comparison with the control was when calcium nitrate with calcium chloride was applied – 120 mg kg^{-1}, the lowest one – when experimental fertilisers with calcium chloride were used – 50 mg/kg. However, both treatments were not significantly different. Calcium chloride alone applied twice was not effective.

In 2002 K/Ca ratio was higher than in either 2001 or 2003, between which no significant differences were found (Table 3). The effect of calcium fertilisers on K/Ca ratio in apples was not significant in most cases.

The average amount of apples affected by bitter pit was low in the years 2003 and 2001: 1.0–1.5% (Table 4). Significantly higher bitter pit incidence was in 2002 – 24.2%.

Table 2. Fruit calcium content (mg/kg of dry weight). LIH, 2001–2003.

Treatment	Year		
	2001	2002	2003
Control	330 ab	197 ab	340 a
$CaCl_2$ x 2	334 b	177 a	363 ab
$Ca(NO_3)_2$ x 5 + $CaCl_2$ x 2	323 ab	207 ab	460 d
Exp. fertilisers x 5 + $CaCl_2$ x 2	330 ab	270 c	390 bcd
Wuxal Ca x 5 + $CaCl_2$ x 2	303 ab	227 b	433 bcde
Average of the treatments	324 b	216 a	397 c

In the present and further tables, means of the treatments within columns and ones of the average of the treatments in the row marked with the same letter do not differ significantly at $P = 5\%$.

Table 3. K/Ca ratio in fruits. LIH, 2001–2003.

Treatment	Year		
	2001	2002	2003
Control	16 a	24 abc	14 abc
$CaCl_2$ x 2	17 a	28 bc	16 c
$Ca(NO_3)_2$ x 5 + $CaCl_2$ x 2	16 a	28 bc	12 a
Exp. fertilisers x 5 + $CaCl_2$ x 2	16 a	21 a	13 abc
Wuxal Ca x 5 + $CaCl_2$ x 2	16 a	23 a	12 a
Average of the treatments	16 a	25 b	13 a

Table 4. Bitter pit incidence (%). LIH, 2001–2003.

Treatment	Year		
	2001	2002	2003
Control	1.9 ab	35.7 c	1.8 b
$CaCl_2$ x 2	1.6 ab	34.9 c	1.2 ab
$Ca(NO_3)_2$ x 5 + $CaCl_2$ x 2	0.5 ab	20.0 a	1.2 ab
Exp. fertilisers x 5 + $CaCl_2$ x 2	2.3 b	13.2 a	0.5 ab
Wuxal Ca x 5 + $CaCl_2$ x 2	1.3 ab	17.1 a	0.5 ab
Average of the treatments	1.5 a	24.2 b	1.0 a

Table 5. Intensity of bitter pit (on 1–10 score scale). LIH, 2001–2003.

Treatment	Year			Average of the
	2001	2002	2003	years
Control	1 a	3.6 e	2 b	2.2 d
$CaCl_2$ x 2	1 a	3.3 cde	1 ab	1.8 bcd
$Ca(NO_3)_2$ x 5 + $CaCl_2$ x 2	1 a	1.8 a	1 ab	1,3 a
Exp. fertilisers x 5 + $CaCl_2$ x 2	1 a	2.4 ab	1 ab	1.5 ab
Wuxal Ca x 5 + $CaCl_2$ x 2	1 a	2.7 bc	1 ab	1.6 ab
Average of the treatments	1 a	2.8 b	1.2 a	

Calcium fertilisers decreased the amount of bitter pit affected apples by 15.7–22.5 percent units. In 2002 calcium chloride applied twice had no positive effect in comparison with the control.

Apple calcium content, K/Ca ratio and bitter pit incidence were different within the years of the experiment. In the dry and warm year 2002, fruits accumulated 177–

270 mg/kg of calcium, K/Ca ratio was 21–28 and bitter pit affected 13.2–35.7% of the apples. In the rest two years, fruit calcium content was 303–460 mg kg^{-1}, K/Ca ratio 12–17 and the amount of bitter pit affected apples was 0.5–2.3%. The data obtained in our experiments are in accordance with the information that apples with a higher calcium content are less susceptible to bitter pit (Tomala, 1997; Dris et al., 1998).

The positive effect of calcium fertilisers on apple calcium content and the highest decrease of bitter pit incidence due to fertilisers were established in different years. An analogical case was reported in the experiments carried out by Greene and Smith (1980): calcium chloride significantly reduced apple infection with cork spots, but did not influence calcium concentration in fruits. Such a paradox could be explained by possible decline of the analysed sample from a whole, as sampling of fruits is rather complicated (Perring, 1974).

Applied fertilisers decreased the intensity of injuries on bitter pit affected apples in 2002, except $CaCl_2$ x 2 that was not significant in comparison with the control. The lowest bitter pit intensity was when calcium nitrate with calcium chloride was applied – 1.8 points (Table 5). Calcium chloride applied twice had not a significant effect on bitter pit intensity.

The effect of tested fertilisers on decrease of bitter pit incidence was similar. Five sprays with calcium nitrate, experimental calcium fertilisers and Wuxal Calcium with two applications of calcium chloride reduced the amount of bitter pit affected apples twice. Calcium chloride applied two times close to the harvest had no effect on bitter pit incidence. Our experiments demonstrate that more intensive application of calcium fertilisers gave better results on bitter pit control.

The information about the role of calcium on fruit firmness, soluble solid content and natural weight loss is different (Tomala & Radecka, 1997; Dris & Niskanen, 1997; Tabataibaie & Malakouti, 1998; Yuri et al., 2002). We did not establish any effect of calcium fertilisers on the mentioned quality parameters.

CONCLUSIONS

Calcium fertilisers had a significant effect on apple calcium content in one year of the experiment. Five applications of calcium nitrate, experimental fertilisers and Wuxal Calcium in combination with two applications of calcium chloride (total CaO rate – 11.9 kg ha^{-1}) raised the fruit calcium content from 340 up to 390–460 mg kg^{-1}. Apple calcium content was influenced by the year. The lowest one was after an extremely dry and warm growth season.

Seven applications of calcium fertilisers significantly decreased bitter pit incidence on ‘Sinap Orlovskij’ apples. On the average, it was twice less in comparison with the control. Calcium chloride applied twice (total CaO rate – 5.9 kg ha^{-1}) close to the harvest had no effect on fruit calcium content and bitter pit incidence. Calcium fertilisers had no effect on apple natural weight loss, soluble solid content and flesh firmness.

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