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Effect of different calcium compounds on postharvest quality of apples

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Abstract. The research was conducted with apple (*Malus domestica* Borkh.) cultivars 'Antei' and 'Talvenauding' in the Rõhu Research Centre and the Estonian University of Life Sciences in 2005–2006. The aim of the study was to determine the influence of different Ca compounds ($CaCl_2$, $Ca(NO_3)_2$ and Boramin Ca) used as preharvest sprays on the mineral content of apple leaves and fruits and apple postharvest quality. Apples were stored in normal atmosphere at 2–5ºC and 80–85% RH. The storage time for 'Talvenauding' was 5 months and for 'Antei' 6 months. The percentage of spoiled apples was calculated monthly. The content of Ca, N, P, K and Mg from apple leaves was determined at the end of August and from fruits after the harvest. The average effect of calcium treatment was significant only in the variant where Ca $(NO_3)_2$ + $CaCl_2$ were used: the percentage of spoiled fruits was 25% compared to 39% in the control variant. Correlation analysis showed that the amount of spoiled fruits in January and at the end of storage had negative correlations with content of Ca in leaves and content of Mg in fruits. At the same time positive correlations were found between N-, P-, K- and Ca content of fruits and spoilage. Only the increasing fruit Mg had a positive effect on apple fruit quality in the present experiment. The content of mineral elements in leaves had no positive correlation with the content of mineral elements in fruits.

Key words: preharvest calcium treatments, storage, spoilage, 'Antei', 'Talvenauding'

INTRODUCTION

The majority of fruit orchards in Estonia are apple orchards. Even though approximately 25 apple cultivars are grown in our orchards, very few have satisfactory quality after four months of storage. After January most apples sold in Estonian markets are imported. 'Talvenauding' is one of the most widely cultivated cultivars for long-term storage in Estonia, having many valuable properties: good winter-hardiness and relatively high vitamin C (18…25 mg $100g^{-1}$FW) content in fruits. 'Antei' is a relatively new but promising cultivar originating from Byelorussia. It has an attractive appearance, also a high content of vitamin C (30…35 mg $100g^{-1}$FW) (Moor, unpublished data) in fruits and a natural wax layer on the skin, which protects the apple from shrivelling. In spite of those valuable qualities, these cultivars also have some severe postharvest problems: superficial scald in 'Talvenauding' and bitter pit in 'Antei'.

In many parts of the world, calcium sprays are used as a routine protective measure, in order to prevent or reduce bitter bit of apples (Saure, 2002). The previous research carried out in Estonia has shown that superficial scald disorder in

’Talvenauding’ is related to mineral nutrition and that fruit content of Ca and its ratios with K, N and Mg play an important role in the severity of scald (Moor et al., 2006). Previous studies showed that if Ca $(NO_3)_2$ was used as Ca source, fruit Ca content did not increase significantly, but fruit N content increased. This is not a favourable result, since it could increase the respiration rate and ethylene production. Also, some studies indicate that application of boron may influence fruit Ca content (Benavides et al., 2002). Therefore, the aim of the present study was to determine the influence of different Ca compounds (with and without nitrogen and boron) on the mineral content of apple leaves and the fruits’ postharvest quality.

MATERIALS AND METHODS

The experiment was conducted from June 2005–March 2006. Apple trees ‘Antei’ and ‘Talvenauding’ were grown in Rõhu Research Centre, which is situated in Tartu County, Southern Estonia. The plantation was 18 years old; rejuvenation was carried out in 1999 and routine thinning has been carried out every year. Apple trees were planted with a distance of 6 m between rows and 4 m within the row. No irrigation system was used in plantation and ‘Antonovka’ was used as seedling rootstock for both cultivars. The number of trees per variant for ‘Talvenauding’ was 21 trees (seven trees in three replications); for ‘Antei’ it was 9 trees (three trees in three replications).

Calcium treatments were the following:

1) control (non-treated);

2) $Ca(NO_3)_2 + CaCl_2$: in this variant $Ca(NO_3)_2$ 1% solution was applied on 1 July and 15 July in the amount of 1000 L ha^{-1} and $CaCl_2$ 0.5% solution was applied on 29 July and 12 August in the same amount; total amount of applied Ca during the summer was 4.9 kg ha^{-1}.

3) $CaCl_2$: only $CaCl_2$ 0.5% solution was applied on all previously mentioned dates and at the same amount; total amount of applied Ca during the summer was 2.22 kg ha^{-1}.

4) Boramin Ca: only Boramin Ca 0.4% solution was applied on all the previously mentioned dates in the amount of 1000 L ha^{-1}. Total amount of applied Ca during the summer was 0.928 kg ha^{-1}.

Apples were harvested in the last week of September. The samples of 90 fruits per variant (thirty fruits in three replications) were collected. Apple fruits were stored in the coolstore of the Raja experimental garden of the Estonian University of Life Sciences at normal atmosphere in 2–5ºC and 80–85% RH. Fruits were set as one layer in air-permeable plastic boxes. The storage period for ‘Talvenauding’ was 5 months and for ‘Antei’ 6 months.

Spoiled apples were removed monthly. The content of Ca, N, P, K and Mg from apple leaves was measured twice: at the end of August and at the end of September, after the harvest. The content of mineral elements was analysed in the Laboratory of Plant Biochemistry of the Estonian University of Life Sciences. The N concentration of air-dried samples was determined by the Kjeldahl method. P and Mg concentrations were measured from a Kjeldahl digest using the flow injection analyzer "FIAstar 5000", K concentration was determined flamephotometrically by an air-acetylene flame. P was determined at a wavelength of 720 nm by the Stannous Chloride method. Mg was determined by the Titan Yellow at a wavelength of 540 nm. Fruit Ca was determined by an induction couplet plasma spectrometer. All nutrient concentrations were expressed as mg kg^{-1} fresh weight (FW).

Weather conditions in summer 2005 could be described as follows: May 2005 was rainy, in fact precipitation rate was double the annual May average for in Estonia; the air temperature was average. In June air temperature and precipitation were somewhat lower than average. July, especially the first part, was exceptionally warm, dry and sunny: the average air temperature was about three degrees higher than average, with only 30% of normal precipitation. August and September were both warmer than average; precipitation was above average in August and below average in September.

The experimental data were analysed by the two-way analysis of variance and correlation analysis. Linear correlation coefficients between variables were calculated, the significance of coefficients being $P < 0.01$**, $P < 0.05$*, *ns* = non-significant.

RESULTS AND DISCUSSION

The percentage of spoiled fruits at the end of storage ranged from 39 to 67% for ‘Talvenauding’ and from 11 to 27% for ‘Antei’ (Fig.1). The average effect of the cultivar was significant: the percentage of spoiled fruits in ‘Antei’ was less than half that in ‘Talvenauding’. The average effect of calcium treatment was significant only in the variant where $Ca(NO_3)_2$ + $CaCl_2$ was used: the percentage of spoiled fruits was 25% compared to 39% in control variant. On average, other Ca compounds did not reduce apple spoilage significantly this year. In different variants, none of the Ca compounds had a significant effect on spoilage.

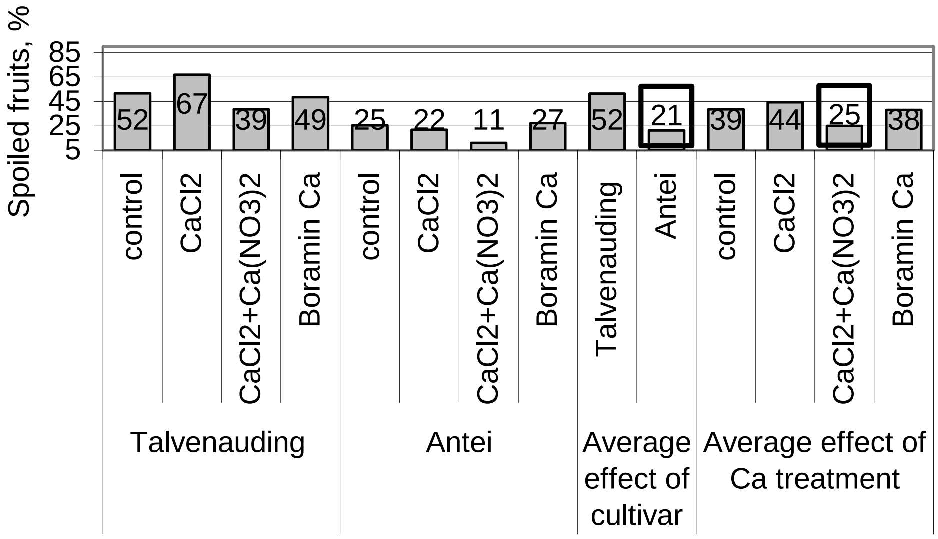

Fig. 1. The percentage of spoiled fruits at the end of storage depending on different preharvest calcium treatments. The mean values to be compared are surrounded with a box (□)if they are significantly different at $P \leq 0.05$.

Correlation analysis showed that the amount of spoiled fruits in January and at the end of storage had negative correlations with the content of Ca in leaves and content of Mg in fruits (Table 1).

Table 1. Correlation coefficients (r) between the mineral content of apple leaves and fruits and the percentage of spoiled fruits after four months of storage and at the end of storage. The asterisks (*) indicate the significance levels of *F*-tests: * $P \leq 0.05$, ** $P \leq 0.01$, *ns* = not significant.

	Mineral content of leaves, g kg^{-1} DM				
	Ca	N	P	K	Mg
Percentage of spoiled fruits after 4 months of storage	-0.393*	-0.162 ^{ns}	-0.027 ^{ns}	0.161 ^{ns}	0.173 ^{ns}
Percentage of spoiled fruits at the end of storage	-0.503**	-0.429*	0.025 ^{ns}	0.117 ^{ns}	0.260 ^{ns}
	Mineral content of fruits, mg kg^{-1} FW				
	Ca	N	P	K	Mg
Percentage of spoiled fruits after 4 months of storage	0.562**	0.524**	0.498**	0.411*	-0.392*
Percentage of spoiled fruits at the end of storage	0.653**	0.625**	0.714**	0.616**	-0.528**

At the end of storage negative correlations were also found between N content in leaves and the amount of spoiled fruits, but positive correlations were found between N-, P-, K- and Ca content of fruits and spoilage. The strongest correlation appeared between fruit P content and spoilage at the end of storage (r = 0,714**). Based on these results it can be concluded that only the increasing fruit Mg had a positive effect on the apple fruit quality in the present experiment.

Considering the results of the present research and also previous studies in Estonia, it appears that the effect of Ca treatment is greatly dependent on the weather conditions and is often useless or has adverse effects in years with low precipitation and high air temperature. Experiments have shown that the warm vegetation period and drought problem during the growing season favour the development of physiological disorders in apples (Lamp, 1981; Dris et al., 1998; Lanauskas & Kvikliene, 2006). In a preharvest Ca treatment experiment carried out in Estonia in 2002, Ca content of 'Talvenauding' and 'Krameri Tuviõun' apples did not reach the level of 50 mg kg^{-1}FW recommended by Sharples (1980). Calcium treatment also had no significant effect on the percentage of spoiled apples (Moor et al., 2006). Experiments carried out in Lithuania showed similar results: apple Ca content was influenced by the year, being the lowest after an extremely dry and warm growth season in 2002 (Lanauskas & Kvikliene, 2006). However, in most parts of the world preharvest Ca treatment is generally effective in increasing fruit Ca and reducing spoilage (Benavides et al., 2001; Neilsen & Neilsen, 2002; Kadir, 2004), possibly because most apple orchards in Europe are drip-irrigated, a method not used in older orchards in Estonia and Latvia.

In the present research, the Ca content of 'Antei' fruits ranged from 23…67 and 'Talvenauding' fruits from 51…98 mg kg^{-1}FW (data not shown), indicating that the recommended level was achieved. Even though the amount of applied Ca was quite different in variants, fruit Ca content was sufficient in most of them. Despite that, fruit spoilage was not reduced. Some other factors could be also very important in determining apple postharvest quality, one being fruit content of Mg. It seems that especially in years with low precipitation, the Mg content of fruit has more often a negative correlation with fruit spoilage than with Ca content of fruit (Moor et al., 2006); (Table 1). Retamales et al., (2000), also stated that the fruit Mg infiltration would provide a more reliable forecast of fruit spoilage than Ca. In the present experiment, fruit Mg of 'Antei' ranged from 42…51 and fruit Mg of 'Talvenauding' from 34…42 mg kg^{-1}FW, which is below the sufficient content and could influence the spoilage of fruits.

Two conclusions can be made from the current research: 1) in dry summers, drip irrigation should be used in orchards to improve apple quality by Ca fertilization; 2) more consideration of adequate Mg content of fruit must be given in order to improve apple postharvest quality.

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