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The effect of late spraying with calcium nitrate on mineral contents in 'Elise' apples

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ABSTRACT

The investigations were carried out in 2004 – 2005 in the experimental orchard at Garlica Murowana in the Krakow area. The effect of late spraying with 0.8% $Ca(NO_3)_2$ on calcium content as well as nutrient mutual relations between mineral constituents in 'Elise' fruit of 5 year old apple tree were studied. Trees were sprayed 3 times at 10-day intervals before fruit harvest. Fruit mineral composition was estimated 10 days after each treatment and after harvest. In general, foliar spray with calcium nitrate increased Ca concentration in fruits determined both after treatments and after harvest however this effect was modified by weather conditions in particular experimental years. Sprays with calcium nitrate significantly decreased N/Ca and K/Ca ratio in fruits analyzed after treatments as well as freshly harvested fruits, however only in 2005.

INTRODUCTION

Calcium provides cell wall rigidity by cross-linking of pectic chains of the middle lamella (Glenn et al. 1988, Tretyn 1994). Disintegration of cell walls and the collapse of affected tissues are typical symptom of calcium deficiency (Marschner 1995). The proportion of calcium pectate in cell walls is very important for the ripening of fruit. The increase of fruit calcium content leads to the increase fruit firmness of fruit and delays fruit ripening or prevents calcium-related disorders (Ferguson and Drobak 1988, Zocchi and Mignani 1995). The presence of available calcium in the nutritive environment does not guarantee the permanent influx of Ca^{+2} ions to different plant organs. Calcium is transported mainly by the appoplast and xylem, stimulated by water potential gradient and hydrostatic pressure (Starck 2003). A fruit is an organ with a low rate of transpiration and in spite of high concentration of calcium in soil solution just a little of this element can be needed (Himelrick and McDuffie 1988). High growth rates of low-transpiring organs increase the risk of calcium tissue content falling below the critical level required for cell wall stabilization and membrane integrity. Even a relatively small increase in the fruit calcium level can be effective in preventing or at least drastically decreasing the economical losses caused by various storage disorders (Saure 2002). Foliar calcium spraying can be an effective way of increasing its concentration in fruits (Casero et al. 2002, Neilsen and Neilsen 2002, Tomala and Soska 2004). The effect of this treatment depends however on environmental factors connected with the technique of spraying, salt concentrations, time and number of treatments and type of fertilizers used (Kahu 2002, Mayr and Schröder 2002, Mengel 2002). Tomala (1997) recommends the first spray of winter apple cultivars with calcium salts at the beginning of June, not later than in the second half of June. According to a great number of studies foliar application of calcium on apple trees was effective in the second half of vegetation period, when the delivery of Ca ions to fruits uptake by roots rapidly decreased (Zavalloni et al. 2001, Casero et al. 2002, Neilsen and Neilsen 2002). Calcium transported by xylem is moved effectively to young fruits, as organs of high metabolism rate and transpiration at the early stage of development. In the later period of fruit growth and ripening the transport of calcium can be limited to floem (Lang 1990), so spraying fruits with calcium solution at this time can increase Ca concentration in fruit tissues.

The aim of the present investigation was to evaluate the effect of late spraying with calcium nitrate applied before harvesting on the mineral content and relations between mineral constituents of 'Elise' apples.

MATERIAL AND METHODS

The investigations were carried out in 2004 – 2005 in the experimental orchard at Garlica Murowana near Krakow. Trees of Elise cultivar, grafted on M.9 were planted in 2000 at 4 × 1.6 m spacing. The soil was kept in the herbicide strips in tree rows with grass between rows.

Every year of the experiment in spring nitrogen soil fertilization was performed at the dose of 50 kg ha^{-1} using ENTEC 26 (26% N including 18.6% N-NH_4 with the addition of nitrification inhibitor). Nitrogen fertilizer was spread around each tree, in the area of herbicide strip.

The experiment was carried out in complete randomized blocks in four replications (6 trees in one replication) and covered:

– control (no foliar spraying),
– tree spraying was done with 0.8% calcium nitrate with the addition of the surfactant Aptolan 80EC (76% of paraffin oil) in the amount of 1000 l ha^{-1}. The sprayings at 10 day intervals started in August, about 30 days before the harvest.

Soil analysis

Soil samples were taken from the layers of 0-20 cm and 20-40 cm, each separately from herbicide stripes and grass strips, at the time of taking leaf assays. Nutrient content in soil was estimated according to the Egner-Riehm (P and K) and Schachtschabel (Mg) methods as well as by universal methods (Ca). PH in water suspension (pH_{H2O}) and in 1 M KCl (pH_{KCl}) in the soil : water (or soil : solution) ratio 1 : 2 were measured. In soil samples granulometric analysis by the aerometric method of Prószynski (Sady et al. 1994) and the organic carbon content by Turin's method were determined (Ostrowska et al.1991).

Leaf analysis

To estimate the nutritive status of the trees the leaf samples were analyzed every year at the end of July or the beginning of August. Samples of 10 mid-shoot leaves from current season terminal shoots on the periphery of each tree were collected. Plant material dried at 70°C was digested in the mixture of HNO_3, $HClO_4$ and H_2SO_4 (6 : 2 : 0.8). The contents of K, Mg and Ca were measured by atomic absorption spectrometer using the flame method, P was detected by spectrophotometric method with ammonium molybdate. Total nitrogen in leaves was determined by Kjeldahl's methods (Ostrowska et al. 1991).

Fruit analysis

Ten days after each foliar spray with calcium nitrate fruit samples were taken from the outer part of the tree, at the height of 1 m. Average fruit weight and dry matter as well as N, K, Mg and Ca contents were detected after mineralization in acid mixture as previously described.

The yield of fruits and their mineral composition at the harvest was also estimated.

Fisher test was applied to evaluate the significance of differences between the means, at the significance level of 5%.

RESULTS AND DISCUSSION

The experimental orchard was established on heavy soil (>35% of loam fraction) of silt loam with a low pH_{KCl} 3.98-4.24. Organic carbon ($C_{org.}$) content in the humus layer (0-20 cm) of herbicide stripe was 0.88%, and in grass strip – 0.70%. Phosphorus and magnesium content was high (> 4 mg P 100 g^{-1} and about 6 mg Mg 100 g^{-1}, respectively) both in the herbicide and grass stripe samples of 0-20 cm and 20-40 cm layers, while potassium content was average (16.3-22.4 mg K 100 g^{-1}) (Table 1). Potassium to magnesium ratio (K/Mg) in the soil was proper, lower than 3.5. The content of available calcium in the soil ranged between 25-40 mg 100 g^{-1} and, according to Komosa and Stafecka (2002) report, was optimum for fruit trees.

Table 1. Contents of P, K, Mg and Ca in the orchard soil

Factor		pH w KCl	P	K	Mg	Ca	K/Mg
			(mg 100 g^{-1})				
Years	2004	4.35	4.09	20.4	6.70	38.1	3.0
	2005	3.89	5.76	18.3	5.57	27.8	3.3
Place of sampling	Herbicide strip	4.19	5.05	19.1	5.87	38.8	3.2
	Grass strip	4.05	4.80	19.7	6.41	27.4	3.1
Soil layer (cm)	0-20	4.17	5.58	22.4	6.09	32.6	3.7
	20-40	4.06	4.27	16.3	6.19	33.6	2.6

Leaf analysis

In both years of the experiment magnesium and calcium contents detected in the leaves ranged in the optimum values for the apple tree (Table 2). Phosphorus level in the indicator parts of the apple tree reached the optimum in 2004, however, it was lower in 2005. In the case of phosphorus and calcium lower contents of these constituents were determined in 2005. The weather conditions also affected nitrogen level in leaves. In 2004 its content was in optimum while in 2005 in high range (more than 2.4% N in dry matter). In both years of the experiment high (>1.5% K in d.m.) potassium concentration in the apple tree leaves was observed.

Table 2. Nutrient contents in 'Elise' apple leaves

Year	Treatment	N	P	K	Mg	Ca
		% d.m.				
2004	Control	2.32	0.17	1.62	0.28	1.87
	0.8% $Ca(NO_3)_2$	2.38	0.16	1.64	0.23	1.81
2005	Control	2.45	0.15	1.74	0.24	1.29
	0.8% $Ca(NO_3)_2$	2.52	0.14	1.69	0.24	1.43
$LSD_{0,05}$ for						
	Year	n.s.	n.s.	n.s.	n.s.	0.154
	Treatment	n.s.	n.s.	n.s.	n.s.	n.s.
	Year × Treatment	n.s.	n.s.	n.s.	n.s.	n.s.

n.s.– not significant

Fruit analysis

Fruits harvested and analyzed 10 days after each foliar application in 2004 had a higher average weight (about 200 g) as compared to those from the second experimental year (about 180 g). Their dry matter was also higher than of the fruits analyzed in 2005 (Table 3). Treatments with calcium nitrate significantly increased the average weight of fruits and decreased their dry matter only in 2004. Both calcium concentration in one kilogram of fresh matter and Ca content in one fruit were higher in 2004. In both years of the experiment fruits picked from the trees fed with $Ca(NO_3)_2$ had more calcium than those from the non-treated ones. In Table 4 the results of the mineral composition of apple fruits, taken for analysis 10 days after each foliar treatment with calcium nitrate are presented. Climate conditions in the individual years of the experiment significantly affected magnesium and calcium content of 'Elise' apples. In the fruits analyzed in 2005 lower Mg and Ca levels were determined, while the average nitrogen and potassium content was similar in both experimental years.

In general, in both years of the experiment the time of fruit analysis significantly affected K, Mg and Ca content as well as N/Ca and K/Ca ratio. This dependence was not observed in the case of nitrogen. Fruit examined at the first term of analysis were characterized by significantly higher potassium, magnesium and calcium contents. The increase of fruit weight was accompanied by the reduction of its constituents. This relation in the case of magnesium and calcium was more distinct in the treatment without calcium nitrate application. According to Plisek (1995), calcium content in fruit increases linearly with the growing of fruit weight from June to the harvest time. Bigger fruits have in general higher content of constituents, but their concentration is lower as compared with smaller fruits. In the present study foliar calcium application maintained Ca concentration in fruits at the same level despite their increasing weight.

Table 3. The effect of late spraying with calcium on fruit weight. dry mass and Ca accumulation in a fruit for 'Elise' apple (measured 10 days after sprays)

Year	Treatment	Fruit weight (g)	Dry mass (%)	Ca content (mg kg^{-1})	Ca quantity in a fruit (mg)
2004	Control	200.8 a*	15.5 a	34.75 a	6.98 a
	0.8% $Ca(NO_3)_2$	219.6 b	14.7 b	36.26 a	7.96 b
2005	Control	181.6 a	12.6 a	27.85 a	5.06 a
	0.8% $Ca(NO_3)_2$	178.6 a	11.6 a	33.47 b	5.98 b

* values marked with the same letter are not differ significantly at p = 0.05

Foliar application of calcium in the form of 0.8% calcium nitrate solution increased Ca content in fruit, determined after 10 days of each treatment (Table 4). In the first year of the experiment the increase was negligible (1.6 mg kg^{-1}of fresh weigh, on average) while in 2005 about 20% (5.7 mg kg^{-1}of fresh weigh) increase was noted as compared with fruits from the non-treated trees. Baab (1997) reports that several spraying of apples with calcium salts can increase the content of these constituents by 5-8 mg Ca mg kg^{-1} of fresh weigh. According to this author, even a slight increase of Ca concentration, can reduce the risk of bitter pit.

Calcium nitrate spray significantly lowered magnesium content in the fruit harvested in 2004. This dependence was observed at all terms of fruit samples analyses (Table 4). Similar results were observed by Gallerani et al. (1990) who found significant decrease of magnesium and potassium contents in apple fruit fed with calcium salts.

Foliar treatment with calcium significantly reduced N/Ca and K/Ca ratio in fruits taken and analyzed 10 days after treatments (Table 4). This effect was however modified by weather conditions in the experimental seasons and was much more distinct in 2005.

In the fruits from both the control trees and those treated with $Ca(NO_3)_2$ nitrogen/calcium ratio was, as reported by Baab (1997), within the usual range, e.g. 10-20 N/Ca. Higher ratio increased possibility of storage disorders (Lafer 1995). In the present investigations potassium/calcium relation was high (e.g > 30) in both experimental years. According to Tomala (1997), the storage ability of apples depends more often on K/Ca ratio than on individual contents of these constituents. Proper relation between these compounds should be within 25-30 range. In spite of high K/Ca ratio in 'Elise' apples no enhancement of the storage disorders was observed (unpublished data).

Table 4. The effect of late Ca sprayings on N, K, Mg i Ca (mg kg^{-1} d.m.) concentration in 'Elise' fruit (measured 10 days after sprayings)

Year	Treatment	Term	N	K	Mg	Ca	N/Ca	K/Ca
			mg kg^{-1} d.m.					
2004	No treatment	I	471	1241	83.1	43.1	11	29
		II	504	1143	70.8	31.3	16	36
		III	517	1038	59.9	29.9	17	35
		Mean	497	1141	71.2	34.7	15	33
	0.8% $Ca(NO_3)_2$	I	520	1254	61.0	39.1	13	32
		II	436	1124	53.9	31.0	14	36
		III	489	1044	60.4	38.6	13	27
		Mean	482	1140	58.4	36.3	13	32
Mean			490	1141	64.8	35.5	14	33
2005	No treatment	I	457	1183	50.7	33.2	14	37
		II	522	1145	49.2	25.5	21	46
		III	442	1126	45.6	24.8	18	45
		Mean	474	1151	48.5	27.8	18	43
	0.8% $Ca(NO_3)_2$	I	472	1121	46.9	35.6	13	32
		II	482	1016	47.4	32.6	15	32
		III	525	1047	46.3	32.2	16	33
		Mean	493	1061	46.8	33.5	15	32
Mean			484	1106	47.7	30.6	16	37
		$LSD_{0.05}$ for						
		Year	n.s.	n.s.	4.75	2.35	1.37	3.12
		Treatment	n.s.	n.s.	4.75	2.35	1.37	3.12
		Term	n.s.	65.8	5.82	2.88	1.68	3.82
		Year × Treatment	n.s.	n.s.	6.72	n.s.	n.s.	4.41
		Year × Term	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Treatment × Term	37.9	n.s.	n.s.	4.07	2.38	5.41

n.s. – no significant

Yield

Yielding of trees was similar in both experimental years (Table 5). Apple yields in 2004 as well as in 2005 were higher in the case of the trees treated with calcium nitrate as compared to the non-treated ones however the differences were statistically non significant. In 2004 the average yield obtained from the trees treated with calcium nitrate and from non-treated (control) ones was 16 kg and 14.9, respectively, while in the next year 16.9 and 13.4 kg, respectively.

Higher mean fruit weight was found in the apples harvested in the first year of the experiment. Spraying trees with calcium nitrate significantly increased fruit weight only in 2004. This dependence was not observed in the second experimental season (Table 5).

Calcium content in 'Elise' apples analyzed at harvest time ranged between 30.1-35.9 mg kg^{-1} of fresh matter. Foliar treatments with calcium significantly increased Ca concentration in fruit only in 2005. Calcium content calculated for one fruit was however significantly higher in fruits treated with calcium nitrate in both experimental years. The N/Ca and K/Ca ratio determined in the apples, decreased significantly as a result of the applied treatments only in 2005.

Table 5. Effect of early sprayings of Ca on harvest fruit weight dry mass and Ca concentration in a harvested fruit for 'Elise' apple

Year	Treatment	Crop (kg per tree)	Fruit mass (g)	Ca concentration (mg kg^{-1} f.m.)	Ca quantity in a fruit (mg)	K/Ca	N/Ca
2004	No treatment	14.9 a*	218.1 a	31.3 a	6.83 a	33 a	13 a
	0.8% $Ca(NO_3)_2$	16.0 a	238.5 b	31.4 a	7.49 b	32 a	14 a
2005	No treatment	13.4 a	197.2 a	30.1 a	5.94 a	35 b	17 a
	0.8% $Ca(NO_3)_2$	16.9 a	190.8 a	35.9 b	6.85 b	31 a	11 b

*see Table 3

CONCLUSIONS

– Treatment of apple trees with calcium nitrate solution increased significantly Ca content and reduced N/Ca and K/Ca ratio in fruits, determined 10 days after each treatment.
– Foliar sprayings with calcium before harvesting significantly increased Ca concentration in apples only in 2005. Calcium content calculated per one fruit was however significantly higher in the fruits treated with calcium nitrate in both years of the study.
– N/Ca and K/Ca ratio determined in the fruits at the harvest time significantly decreased as a result of the applied treatment only in 2005.

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WPŁYW PÓŹNYCH OPRYSKIWAŃ SALETRĄ WAPNIOWĄ NA ZAWARTOŚĆ SKŁADNIKÓW MINERALNYCH W OWOCACH JABŁONI ODMIANY 'ELISE'

Streszczenie: Badania prowadzono w latach 2004 – 2005 w Sadzie Doświadczalnym w Garlicy Murowanej koło Krakowa. Określano wpływ późnego opryskiwania jabłoni 0.8% $Ca(NO_3)_2$ na zawartość wapnia oraz wzajemne proporcje pomiędzy składnikami mineralnymi w jabłkach z 5 letnich drzew odmiany 'Elise'. Drzewa opryskiwano 3-krotnie w odstępach 10-dniowych przed zbiorem owoców. Zawartość składników mineralnych w jabłkach oznaczano 10 dni po każdym zabiegu oraz po zbiorze owoców. Ogólnie dokarmianie owoców roztworami saletry wapniowej zwiększało zawartość Ca w owocach oznaczaną zarówno po wykonywanych zabiegach jak i po zbiorze owoców, jakkolwiek efekt ten był modyfikowany przez warunki atmosferyczne panujące w latach prowadzenia badań. Opryskiwania saletrą wapniową istotnie obniżały wartość stosunku N/Ca i K/Ca w owocach we wszystkich terminach analiz, ale tylko w roku 2005.

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