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Effect of frost damage on leaf macronutrient status of eight apple cultivars in integrated apple orchard in Eastern-Hungary

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Summary: The year of 2007 was critical for fruit growers in the region of Easter-Hungary. Several orchards were suffered frost damages. Significant frost damage was also happened in the orchard of Tedej Rt., which caused total fruit failure in the orchard. Our study was conducted in the integrated apple orchard (*Malus domestica* Borkh.) established on a lowland chernozem soil in East-Hungary, to investigate how frost changes the mineral content of different apple species. Leaf samples were collected 100 days after full bloom both in 2006 and 2007. The concentrations of nitrogen, phosphorous, potassium, calcium and magnesium were measured in leaves. The absence of fruits caused a smaller accumulation of nitrogen and magnesium in leaves. Falling down of flowers and fruit sets hindered the translocation of the uptaken phosphorous, potassium and calcium towards fruit sets. Due to fruit failure the vegetative processes became dominant. Leaves larger amount of phosphorous, potassium and calcium stored.Besides the absolute element content, the ratio of the different elements was also determined. Majority of calculated ratios were removed from optimal values due to frost. Both absolute content of nutrients and their ratios pointed out that the frost damage significantly affected the uptake of nutrients and their storing processes.

Keywords: fruit nutrition, apple, frost damage, mineral composition

Introduction

The climate condition and orchard management practises are the main key factors in the production of high and qualitative yields of apples (*Bramlage,* 1993)

In the last few years irregularity of yield is one of the main problems in fruit production. Year-to-year variations in crop production have been traditionally related to weather conditions is spring all over the world (*Rodrigo & Herrero*, 2002). Frost is a dangerous climatic hazard that can be responsible for yield losses and serious injuries to orchard trees. The resistance to frost damage is associated with the nutritional status of plant.

In temperate climates, important damages on deciduous fruit trees are caused in buds, flowers and developing fruits after dormancy and the losses due to frosts during the blooming are usually more important than those due to low winter temperatures (*Rodrigo,* 2000).

2007 was a critical year for fruit growing in Eastern-Hungary. At the beginning of May there were two days when the temperature of early dawn was approximate 3–5 °C. Due to it there was not yield in lot of orchards in this region. The frost damage caused entirely crop failure and created new conditions for plant uptake.

In the orchard of TEDEJ Rt. the flowers and fruit sets of apple trees were fallen down *(Figure 1)*. Due to the frost there was not measurable yield in the orchard.

The aim of our research was to study how frost changes the mineral content of different apple cultivars.

Figure 1 Frost damaged flower cluster (Tedej)

Materials and methods

Our investigations were carried out in 2006 and 2007 in an apple orchard (*Malus domestica* Borkh.) of TEDEJ Rt., Hajdúnánás-Tedej, in Eastern Hungary. The orchard was set up on lowland chernozem soil. It was established in the autumn of 1999, using grafted on MM106 rootstocks at a spacing of 3.8×1.1 m. The orchard has been treated according to the Integrated Fruit Production guidelines.

The orchard was irrigated. Soil samples were taken from three layers (0–20 cm; 20–40 cm and 40–60 cm) of each plot, at the middle of the section by using manual soil sampling equipment. For the characterisation of the soil the most important soil parameters were determined. Sampling was performed at the beginning of the vegetation period on April, in 2006.

The soil samples were dried outdoors in an airy place in a 1-1.5 cm layer, then the soil was sieved through a sieve of 2mm holes size, homogenized and stored in plastic boxes until the examination. For extracting the available phosphorus and potassium content of soils, ammonium-lactate extractant (so called AL soluble) was used. AL soluble phosphorus was quantified by colorimetrically with phospomolybdovanadate method, using a spectrophotometer (Metertech VIS SP-850 Plus; Metertech Inc., Taipei, Taiwan). The amount of potassium was quantified by flame atom emission spectrophotometry method using an Unicam SP90B Series 2 Atomic Absorption/Emission Spectrophotometer (PYE Unicam, England).

Mineralized nitrogen contents and pH of soil samples were quantified according to *Houba* et al., 1986. The K_A, carbonate and humus content of soil were determinated according to Hungarian standards (É MSZ-08-0205:1978; É MSZ-08-0206-2:1978; É MSZ-08-0210:1977).

For plant analysis the following apple cultivars were selected: 'Idared'; 'Topaz'; 'Gala Must'; 'Summerred'; 'Jonagold'; 'Braeburn'; 'Golden Reinders'; 'Mutsu'.

Healthy, fully developed leaves were taken from the mid-third portion of extension shoots current year were collected. Leaf samples were collected 100 days after full bloom, from 50 uniform trees in 2006 and 2007, respectively. Leaf samples were dried outdoors in an airy place for a week. After drying samples in a well-ventilated drying oven for 6 hrs at 40 C, the whole sampled material was finely grounded and homogenized. Samples were then stored in paper bags in a dark and dry place until use.

Nitrogen content of plant samples was determined from homogenized samples directly using the dry combustion method according to Nagy (2000), using an Elementar Vario EL analyser (Elementar Analysensysteme GmbH, Hanau, Germany).

Plant phosphorus and potassium were qualified as described for soil samples.

Calcium and magnesium were measured by flame atomic absorption spectrophotometry, using a SpectrAA-10 Plus spectrophotometer (Varian Australia Pty Ltd. Mulgrave, Australia).

Results and discussion

Soil analysis

Obtained results of soil analysis are represented in *Table 1.*

Table 1 Results of soil analysi

	Depth			
Parameters	0–20	20–40	40–60	**0–60**
pH ($CaCl_2$)	7.43	7.36	7.54	***7.44***
H%	2.95	2.83	2.58	***2.79***
KA		45		
$CaCO_3$%	8.3	8.5	12.5	***9.77***
	mg/kg			
AL-P	164.11	89.12	42.7	***98.64***
AL-K	263.93	160.69	88.65	***171.09***
$CaCl_2$-N_{min}	14.10	9.05	5.44	***9.53***

Besides conventional soil testing procedures, 0.01 M $CaCl_2$ was used to give further information about the easily soluble and available mineral N contents of soil. The pH of soil was near the neutral value. The physical category of soil was clay loam. The soil P and K was medium, while the soil N was suitable for growing.

The values of easily soluble N form correspond to the type of examined soil and decreased by depth.

Plant analysis

Values and status of leaf N, P, K, Ca and Mg at different species in 2006 and 2007 were shown in *Table 2–6.*

In 2006, leaf N was sufficient at most of cultivars (Table 2). In 2007, after frost damage, leaf N was lower at most cultivars, except 'Mutsu' and 'Jonagold'. Remarkable that significantly higher leaf N was measured at 'Mutsu' in 2007 than in 2006. Leaf N was significantly affected by years.

Table 2 Leaf N of eight apple cultivars (2006–2007)

Cultivars	**2006**		**2007**	
	N (%) (d.m.)	**N status**	**N (%) (d.m.)**	**N status**
Idared	2.10	S	1.73	L
Topaz	2.44	S	1.73	L
Gala Must	2.14	S	1.97	L
Summerred	2.19	S	1.70	L
Jonagold	1.87	L	1.89	L
Braeburn	2.20	S	1.91	L
Golden Reinders	1.95	L	1.93	L
Mutsu	2.02	S	2.25	S
Average	***2.11***		***1.89***	
LSD5% (within year)	***0.12***		***0.12***	
LSD5% (without years)	***0.11***			

H – high; S – sufficient; L – low

Table 3 Leaf P of eight apple cultivars (2006–2007)

Cultivars	2006		2007	
	P (%) (d.m.)	P status	P (%) (d.m.)	P status
Idared	0.18	S	0.28	H
Topaz	0.16	S	0.19	S
Gala Must	0.18	S	0.23	H
Summerred	0.18	S	0.38	H
Jonagold	0.14	S	0.14	S
Braeburn	0.26	H	0.34	H
Golden Reinders	0.15	S	0.25	H
Mutsu	0.15	S	0.18	S
Average	***0.17***		***0.25***	
LSD5% (within year)	***0.03***		***0.06***	
LSD5% (without years)	***0.04***			

H – high; S – sufficient; L – low

Table 5 Leaf Ca of eight apple cultivars (2006–2007)

Cultivars	2006		2007	
	Ca (%) (d.m.)	Ca status	Ca (%) (d.m.)	Ca status
Idared	1.22	S	1.24	S
Topaz	1.41	S	1.57	S
Gala Must	1.22	S	1.27	S
Summerred	1.31	S	1.34	S
Jonagold	1.03	L	1.17	L
Braeburn	1.06	L	1.00	L
Golden Reinders	1.04	L	1.39	S
Mutsu	1.29	S	1.38	S
Average	***1.20***		***1.30***	
LSD5% (within year)	***0.10***		***0.12***	
LSD5% (without years)	***0.08***			

H – high; S – sufficient; L – low

From results it was evident that the absence of fruits caused a smaller accumulation of N in leaves in 2007. Leaf area was higher in 2007 than in 2006. The vegetative processes became dominant. Leaf N was affected by cultivars in both years.

In 2006, leaf P was sufficient at all examined cultivars, except 'Braeburn' *(Table 3).* In 2007, higher leaf P was measured at most cultivars than in 2006, except 'Jonagold' at which leaf P was the same amount in both years. Increase of leaf P may be explained with the fruit failure. Falling down of flowers and fruit sets hindered the translocation of the uptaken P towards fruit sets. Leaf P was affected by cultivars. Outstandingly high phosphorus was measured at 'Braeburn' in both years and at 'Summerred' in 2007.

In 2006, leaf K was sufficient at six cultivars. It was low at 'Topaz' and it was high at 'Mutsu' *(Table 4).* In 2007, leaf K was sufficient at four cultivars and it was high at four cultivars also. Higher leaf K was measured at six varieties in 2007 than in 2006. Leaf K was shown similar tendency observed leaf P. Value of leaf K was affected by cultivars also. Extremely low leaf K was observed at 'Topaz' in 2006.

In 2006 leaf Ca was sufficient at five cultivars and it was low at three cultivars *(Table 5).* Values of it were slightly increased in 2007, except 'Braeburn'. Leaf Ca increased significantly at the following varieties: 'Topaz', 'Jonagold', 'Golden Reinders' and 'Mutsu'.

The increase of leaf Ca can be explained by the hindered translocation also. The lack of generative organ resulted a larger Ca accumulation in leaves.

Leaf Mg was higher in 2006 than in 2007 at all studied cultivars. The degree of decrease was significant at all cultivars, except 'Topaz'. The highest leaf Mg was measured at 'Topaz' in 2006 and 2007 respectively. The Mg status of leaf became low at 'Idared', 'Summerred' and 'Braeburn' cultivars in 2007.

Table 4 Leaf K of eight apple cultivars (2006–2007)

Cultivars	2006		2007	
	K (%) (d.m.)	K status	K (%) (d.m.)	K status
Idared	1.11	S	1.40	S
Topaz	0.74	L	1.26	S
Gala Must	1.39	S	1.68	H
Summerred	1.39	S	1.84	H
Jonagold	1.20	S	1.05	S
Braeburn	1.57	S	1.75	H
Golden Reinders	1.57	S	1.19	S
Mutsu	1.67	H	1.82	H
Average	***1.33***		***1.50***	
$LSD_{5\%}$ (within year)	***0.21***		***0.22***	
$LSD_{5\%}$ (without years)	***0.15***			

H – high; S – sufficient; L – low

Table 5 Leaf Mg of eight apple cultivars (2006–2007)

Cultivars	2006		2007	
	Mg (%) (d.m.)	Mg status	Mg (%) (d.m.)	Mg status
Idared	0.31	S	0.22	L
Topaz	0.49	H	0.47	H
Gala Must	0.37	S	0.31	S
Summerred	0.36	S	0.23	L
Jonagold	0.34	S	0.30	S
Braeburn	0.31	S	0.20	L
Golden Reinders	0.34	S	0.30	S
Mutsu	0.33	S	0.27	S
Average	***0.36***		***0.29***	
LSD5% (within year)	***0.04***		***0.06***	
LSD5% (without years)	***0.04***			

H – high; S – sufficient; L – low

Binary macronutrient ratios

Besides the absolute element content, the ratio of the different elements was also determined according to Papp (1997) and Füleky (1999). Our assumption is that these ratios can provide a better indication of nutritional status than conventional sufficiency range approaches. It has been suggested that using these ratios minimize the effects of dilution or concentration due to dry matter and age factors and better evaluates possible nutritional interactions.

From results, the most frequently used ratios were calculated from the main average of cultivars *(Table 6)*.

Table 6 Calculated binary macronutrient ratios

	N/P	N/K	N/Ca	N/Mg
2006	12.41	1.59	1.76	5.86
2007	7.56	1.26	1.45	6.52
Optimal	***14.38***	***1.77***	***1.53***	***6.97***
	P/K	**P/Ca**	**P/Mg**	
2006	0.13	0.14	0.47	
2007	0.17	0.19	0.86	
Optimal	***0.12***	***0.11***	***0.48***	
	K/Ca	**K/Mg**		
2006	1.11	3.69		
2007	1.15	5.17		
Optimal	***0.87***	***3.94***		
	Ca/Mg			
2006	3.33			
2007	4.48			
Optimal	***4.55***			

The ratio of N/P was almost twice as much in 2006 than in 2007. The significant decrease of it was explained by the contrary changing of N and P content of leaf.

The ratio of N/K and N/Ca were lower in 2007 than in 2006 also. The opposite was true for the N/Mg ratio. This contrary tendency was pointed out that the degree of decreasing of leaf Mg was higher than the decreasing of leaf N. The ratio of P/K, P/Ca and P/Mg increased which means the ratio of their removed from the optimal value because these ratios were near the optimal values in 2006.

Similar tendency was observed regarding K/Ca and K/Mg ratios. It means that founded harmonies between these elements in 2006 were overturned.

The ratio of Ca/Mg was increased also. This changing came the ratio of Ca/Mg closer to the optimal value. Both absolute content of nutrients and their ratios pointed out that the frost damage significantly affected the uptake of nutrients and their storing processes.

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