

Effect of foliar fertilization on leaf mineral composition, sugar and organic acid contents of sweet cherry

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Summary: Influence of a three-year-long foliar fertilization on mineral composition of leaf, content of sugars (glucose, fructose, galactose and sucrose) and organic acids (citric, malic and fumaric acid) of sweet cherry (*Prunus avium* L.) fruits was studied. The experiment was conducted during 2005–2007 in West Hungary on mature cv. 'Germersdorfi 3' grafted on *Prunus mahaleb* rootstock, planted in 1999. Trees spaced 7 x 5 m, and growing in a calcareous chernozem soil. Trees were foliar-fertilized with potassium (K) as KNO₃ and calcium (Ca) as Ca(NO₃)₂. Potassium spraying was carried out 3 (K₁) and 5 (K₂) while calcium was applied at 3 (Ca₁), 5 (Ca₂) and 6 (Ca₃) weeks after full bloom. Beside fruit analysis, complete soil and leaf analysis were done to study the rate of nutrient uptake and its effects on fruit quality. Contents of nutrients of soil and leaf were determined by atomic absorption and spectrophotometric method, while sugars and organic acids in fruit were determined by HPLC. The applied treatments (except K₁) had been increasing leaf K significantly compared to the control till ripening. Most of treatments had no significant effect on Ca content of leaf till ripening. From applied treatments only the boron treatments had significant increasing effect on contents of all examined sugars, compared the control. Furthermore, the effect of calcium spraying on the contents of organic acids was significant.

Key words: cherry, foliar nutrition, fruit quality, sugars and organic acids

Introduction

Foliar fertilization had become a widespread management tool in important fruit growing areas, often as a complementary practice to soil nutrition supply.

Foliar application of mineral nutrients using sprays supplies nutrients to plants more rapidly than soil/root applications. But this method has transient effects and may cause leaf damage (necrosis and "burning"). Moreover, this technique, if properly applied, had an interesting and partially unexploited potential for manipulating yield and fruit quality, with relatively low costs and low environmental impact (Tagliavini et al., 2002).

However, foliar fertilization has been widespread all over the world there is only limited information about its Hungarian applications.

The role of K and Ca in fruit growing is prominent. Beside several factors K is vital importance in increasing fruit growth, as well as in carbohydrate storage and Ca is responsible for fruit cracking. Moreover these nutrients are essential for reproduction, aid in the metabolism of hormones, sugars and growth regulators.

Favourable fruit quantity and quality unimaginable without proper K and Ca supply.

The influence of K and Ca foliar fertilization on leaf minerals, content of sugars (glucose, fructose, galactose and sucrose) and organic acids (citric, malic and fumaric acid) was studied on sweet cherry (*Prunus avium* L.) cv. 'Germersdorfi 3' grafted on *Prunus mahaleb* rootstock.

Material and methods

Experimental site and fertilization

The experimental orchard was located at Siófok, in South-West Hungary. The study was conducted during 2005–2007 on cv. 'Germersdorfi 3' grafted on *Prunus mahaleb* rootstock. Trees were planted in the spring of 1999. Trees spaced 7m (between rows) x 5 m (within rows), and growing in a calcareous chernozem soil. Orchard was not irrigated in the examined period. K and Ca foliar fertilization was applied to study its effect on leaf and fruit contents. For the purpose of the experiment, 3x10 trees were randomly

selected from a population of trees with uniform characteristics.

Calcium and potassium treatment was fulfilled with calcium nitrate and potassium nitrate spraying, respectively. The applied foliar applications are presented in *Table 1*.

Table 1 Applied foliar fertilization system (2005–2007)

Applied nutrient	Dose (kg ha ⁻¹)	Time of applications	Code of treatment
Control	–	–	C
K as KNO ₃	0.5	3 weeks after full bloom 3 and 5 weeks after full bloom	K ₁ K ₂
Ca as Ca(NO ₃) ₂	0.75	3 weeks after full bloom 3 and 5 weeks after full bloom 3, 5 and 6 weeks after full bloom	Ca ₁ Ca ₂ Ca ₃

Soil sampling and preparation

Two soil samples were collected from three layers (0–20, 20–40 and 40–60 cm) of each treatment by using manual soil sampling equipment following the Hungarian sampling guidelines and the study of Nagy et al. (2006). Sampling was performed before treatments, at the beginning of the vegetation period in 2005. Sample preparation of the soil samples was performed according to Hungarian guidelines (MSZ 20135:1999). The following parameters were measured: pH, K_A, content of humus and AL soluble P and K according to Hungarian guidelines.

Plant sampling and preparation

Leaf samples were taken, from May to September (20, 35, 100 (at ripening) and 170 days after full blooming, respectively) from 2005 to 2007, annually. Healthy, fully developed leaves were taken from the mid-third portion of extension shoots current year were collected.

Leaf samples were washed with distilled water to remove dust and possible remains of pesticide, than 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.

Calcium and magnesium were determined via atomic absorption spectrophotometry (Varian SPECTRAA 20). Potassium was determined by flame atom emission spectrophotometry (Unicam SP90B Series 2 Atomic Absorption/Emission Spectrophotometer (PYE Unicam, England)).

Fruits were collected at ripening in 2007. Approximately 1 kg fruit was picked per tree. Sugars (glucose, galactose, fructose and sucrose) in fruit were determined by HPLC (AOAC Method 992. 14). Thermo Hypersil column AP-2 100×3 mm was used (eluent was CH₃CN:H₂O=8:2 (v/v)) and LSD (30 °C, spraying pressure: 350 kPa) detector.

Organic acids (citric, malic and fumaric) in fruit were determined by HPLC according to García-Alonso et al., (2006). For determination Hypersil BDS C8, (250×4.6 mm,

5μ) column was used (eluent was 0.2 M K₃PO₄:MeOH=9:1 (v/v)) and UV detector with wavelength at 254 nm for identification.

Vitamin C in fruit was determined by HPLC also. For determination Spherisorb ODS C18 (15×4.6, 5 μm) column was used (eluent was: 0.01%-os K₂SO₄ (pH=2.6); flow rate was: 1 ml/min) and UV-VID DAD detector with wavelength at 245 nm for identification.

Results and discussions

Soil analysis

The orchard soil type is calcareous chernozem soil. The upper layer of soil (0–60 cm) contained 1.7 % humus, 178 mg/kg and 372 mg/kg AL-soluble P and K. The plasticity index according to Arany (K_A) was 39. According to our results the soil is slightly alkaline (pH (H₂O)=7.65) loamy soil and calcareous in deeper layers. According to our data soil N-supply was weak, soil P-supply was medium and soil K-supply was adequate for growing.

Plant analysis

In this paper we show the results of leaf and fruit analysis of 2007 only, to investigate the cumulate effect of three-year management.

Leaf mineral composition

According to the reference curves leaf K continuously decreased from May to September except the control, where it slightly increased in September (*Table 2*).

The applied treatments (except K₁) had been increasing leaf K significantly compared to the control till ripening. Leaf K was low in most treatments at ripening. It is contrary the results of soil analysis.

All treatments increased leaf Ca content continuously till ripening (*Table 3*). Then it declined in most treatments except Ca₁ and Ca₃. Most of treatments had no significant effect on Ca content of leaf till ripening. Measured leaf Ca

Table 2 The leaf K content (g/100g)

Treatment	Sampling time			
	20 DAFB	35 DAFB	100 DAFB	170 DAFB
C	2.32	1.64	0.68	1.09
K1	2.32	1.50	0.82	0.82
K2	2.73	1.91	1.23	0.82
Ca1	2.32	2.18	1.77	1.09
Ca2	2.45	2.18	1.50	1.09
Ca3	2.32	2.05	1.09	0.95
Average	2.41	1.91	1.18	0.98
LSD_{0.05}	0.13	0.23	0.33	0.11

DAFB-days after full bloom

Table 3 The leaf Ca content (g/100g)

Treatment	Sampling time			
	20 DAFB	35 DAFB	100 DAFB	170 DAFB
C	1.10	2.33	3.71	3.40
K1	1.00	2.31	3.48	3.36
K2	1.16	2.37	3.70	3.18
Ca1	1.07	2.35	3.60	4.27
Ca2	1.12	2.17	3.74	3.19
Ca3	0.92	2.33	3.61	4.02
Average	1.06	2.31	3.64	3.57
LSD_{0.05}	0.07	0.06	0.08	0.37

DAFB-days after full bloom

values were high at ripening. We suppose that the excessive Ca supplies resulted limited potassium uptake by tree.

From seasonal data of K and Ca, it was evident that the requirement of K and Ca for plant growth changes with the developmental stages and their uptake pattern differ from each other.

Therefore, their timely application is an important factor for achieving better plant growth and yield.

Sugars content of fruit

The contents of glucose, galactose, fructose and sucrose are presented in *Table 4*. Our results for the monosaccharides investigated were a bit lower to those reviewed by *Wrolstad & Schallenberger* (1981) who reported mean values for a large variety of cherries as glucose 7.78 g/100 g; fructose 7.09 g/100 g and *Gardiner et al.*, (1993) who reported the content of glucose is 7.025 g/100 g and fructose is 6.7 g/100 g approximately. Nevertheless *Girard & Kopp* (1998) pointed out that major sugars and organic acid constituents varied widely among sweet cherry cultivars. Our values are also comparable to those obtained by *Wills et al.* (1987) for Australian cherries and by *Dolenc and Stampar* (1998) in Slovenia. Galactose and sucrose were lower amount in the unprocessed cherries, which is consistent with the findings of *Wrolstad and Schallenberger* (1981).

Furthermore, our results confirmed those earlier results as the content of glucose and fructose is present in approximately equal and large amounts in most nectar (*Van Handel et al.*, 1972).

Galactose and sucrose were near equal amount in cherry. Their amount was approximately six percent of glucose and fructose.

Treatments had inconsistent effects on investigated content of sugars (*Table 4*). Only the Ca₁ treatment increased glucose content of fruit. The galactose content of fruit was the highest at the control treatment. All treatments increased fructose content of fruit, except Ca₂. From applied treatments, only the K₁ decreased sucrose level in fruit significantly compared to the control (*Table 4*.)

Table 5 The content of organic acids (mg/100g fresh weight)

Treatment	Vitamin C	Citric acid	Malic acid	Fumaric acid
	mg/100g fresh weight			
C	8.00	12.20	908.40	0.05
K1	9.7	12.30	922.60	0.06
K2	9.4	13.60	958.70	0.08
Ca1	8.6	12.40	920.70	0.06
Ca2	9.1	13.00	947.80	0.08
Ca3	8.8	13.20	952.70	0.09
Average	8.93	12.78	935.15	0.07
LSD_{0.05}	0.48	0.45	16.42	0.01

Table 4 The content of sugars (g/100g fresh weight)

Treatment	Glucose	Galactose	Fructose	Sucrose
	(g/100g fresh weight)			
C	5.29	0.27	5.12	0.23
K1	5.40	0.18	5.31	0.32
K2	4.91	0.23	5.23	0.21
Ca1	5.84	0.24	5.33	0.22
Ca2	5.17	0.19	5.10	0.19
Ca3	4.99	0.23	5.24	0.20
Average	5.27	0.22	5.22	0.23
LSD_{0.05}	0.27	0.03	0.08	0.04

Acids content of fruit

All of K and Ca treatments significantly increased the content of vitamin C of cherry fruit. The highest content of vitamin C was measured at K₁ treatment (*Table 5*).

The contents of investigated acids are presented in *Table 5* also. Our results for the organic acids were similar to those reviewed by *Girard & Kopp* (1998) who described that malic acid varied widely (502.7–948.3 mg/100 g of fresh weight) among cultivars of sweet cherry. Malic acid is the principal metabolic substrate together with sugars (*Ackermann et al.*, 1992). Malic acid was present in cherry fruits in higher contents than other organic acids. Amount of it was approximately nine times more than the amount of citric acid. The content of fumaric acid was negligible compared to citric and mostly malic acid. Founded ratios are comparable to earlier findings by *Usenik et al.* (2005) and *Spinardi et al.* (2005), who investigated the rootstocks effect on fruit quality. From applied treatment only the K₂, Ca₂ and Ca₃ increased malic, citric and fumaric acid significantly as well. From results it was established that only repeated K and Ca treatments resulted significant effects on organic acids of cherry fruit.

It is concluded that under conditions of this experiment, repeated K and Ca foliar fertilization can be recommended in sweet cherry culture to improve organic acids of fruit. Moreover this effect was inconsistent at investigated sugar contents.

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