Does foliar nutrition influence the pear fruit quality?

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Summary: The influence of the foliar nutrition on the pear fruit quality *(Pyrus communis* L.) cv. 'Williams' was studied in years 1997 and 1998. We determined the contents of individual sugars (glucose, fructose, sucrose and sorbitol) and organic acids (malic, citric, fumaric and shikimic) by HPLC (High Performance Liquid Chromatography). The sizes of the fruits (diameter, length, weight) were measured as well as the amounts of soluble solids and titrable acids. The experiment comprised two treatments: the foliar nutrition and the control. In the treatment of foliar nutrition the trees were sprayed five times (from May 22 to July 7) with a foliar fertilizer, which contained 15% of P_2O_5, 20% of K_2O, 0.1% of Mn, 0.1% of B and 0.1% of Mo. The foliar nutrition influenced higher quantities of sugars (glucose, sorbitol, soluble solids) and organic acids (malic, citric) but had no effect on the contents of shikimic acid, pH juice and titrable acids. At the treatment of foliar nutrition a trend of decrease in the contents of fructose, sucrose, fumaric acid, boron, and zinc was noticed.

Key words: pear, *Pyrus communis* L., foliar nutrition, fruit quality, organic acids, sugars

Introduction

In fruit growing practice the determination of adequate soil mineral content is of basic importance. We can determine the amount of necessary main and trace elements on the base of soil and also leaf analyses. Good utilization of fertilizers is often limited by factors like lime content, weather condition and growing methods (*Szücs* & *Kállay*, 2000). The soil lime content has a negative effect on P and K uptake, yield of peach and P content in soil (*Szücs*, 1995). The N and Ca content in leaves increased with yields, when K and P content formulated reciprocally. Potassium fertilization – principally high doses of potassium – increased crop quality, but increased the incidence of physiological diseases occurring during storage as well. Lower crops were correlated to oversupply of potassium and undersupply of phosphorus, while nitrogen status was neutral (*Szücs* et al., 1990). *Szücs* (1996) reported that N and P had only small effects on leaf nutrient content, had a favourable effect on fruit set, but yield was increased only by potassium in sour cherry. The water supply during the fruit development has an influence on the reception of nutrients into the fruits and also on the content of the individual sugar contents and organic acids in fruits (*Hudina* & *Štampar*,, 1999a). The available nutrients in the soil influence the reception of the main and the trace elements into the fruits. The content of individual sugars, organic acids, main and trace elements are very important as they determine the internal quality of fruits (*Hudina* & *Štampar*, 1999b). The fruits containing high quantities of sugars and organic acids together with the optimal mineral contents are of better quality and therefore more suitable for a longer storage (*Hudina* & *Štampar*, 2000a).

Our goal in the research work was to establish the influence of foliar nutrition on the external and internal quality of fruit, i.e. on the contents of sugars and organic acids, main and trace elements.

Material and method

The sugar content (glucose, fructose, sucrose and sorbitol) and organic acids (citric, malic, shikimic and fumaric) were studied at harvest (August 17, 1997 and August 23, 1998) in the cultivar 'Williams' on the quince MA. The experiment encompassed two treatments: foliar nutrition and control. At the treatment of foliar nutrition the trees were sprayed with a foliar fertilizer, which contained 15% P, 20% K, 0.1% Mn, 0.1% B and 0.01% Mo, in a 2 l/ha measure. In the foliar fertilizer phosphorus was in the compound of P_2O_5, potassium in K_2O, boron in boric acid, manganese in Mn-(EDTA) and molybdenum in ammonium molibdate. We used the foliar fertilizer for five times (22 and 28 May, 5 and 16 June and 7 July). 12 trees were included per treatment (4 blocks with 3 trees per plot). One fruit from each tree was used to determine contents of sugars and organic acids.

Samples for HPLC analysis were prepared firstly by homogenisation with manual blender (Braun), then with Ultra-Turrax T-25 (Ika – Labortechnik). 10 g of mashed fruit were dissolved in bidistillated water up to 40 ml and centrifuged at 6000 rotation/min for 15 min. The extract was filtered through 0.45 µm Minisart filtre (RC-25, Sartorious). For each HPLC analysis of sugars and organic acids 20 µl of sample was used (*Dolenc* & *Štampar*, 1997).

HPLC method was used for separation, identification and quantification of individual compounds in pear puree. The HPLC system consisted of Thermo Separation Products (TSP), USA, equipment with model P1000 pump, autosampler model AS1000, column heater and OS/2 Warp IBM Operating system (1994)-work station. Solute elution was monitored using a variable wavelength UV detector (Knauer, Germany) set at 210 nm and differential refractive index RI (model Shodex-71 RI, Japan).

Sugars (glucose, fructose, sucrose and sorbitol) were analysed isocratically on the Aminex – HPX 87C (300 x 7.8 mm) cartridge (Bio-Rad, USA) with an eluent flow rate of 0.6 ml/min and at 85 °C with bidestillated and on-line degassed water used as eluent. Attenuation of the refractive index detector was set at 16x. Sugars present in each sample were identified by the comparison of the retention time of each peak with those of standard sugars. The concentration of each sample was calculated by comparison of peak areas to the area of calibrated sugar solutions of known concentrations (method of external standard). The reproducibility of the chromatographic separation of the components was determined by making six injections of the standard solutions and pear sample. The results expressed as relative standard deviation (RSD%) are as follows: 0.27 for glucose, 0.28 for fructose, 0.29 for sucrose and 0.26 for sorbitol.

Organic acids (malic, citric, shikimic and fumaric) were analysed on the Aminex – HPX 87H (300 x 7.8 mm) cartridge (Bio-Rad, USA) with the flow of 0.6 ml/min and at 65 °C. For mobile phase 4 mM sulphuric acid was used. Organic acids were identified and quantified by using UV detector with wavelength set at 210 nm and by comparison of retention times and peak areas with standard solution of known organic acids. Results of the reproducibility study of chromatographic separation for organic acids expressed as relative standard deviation (RSD%) are as follows: 0.30 for malic acid, 0.31 for citric acid, 0.15 for shikimic and 0.13 for fumaric acid.

The standards employed are the products of Fluka Chemical (New York, NY, USA), except for the malic acid which is a product of Merck Chemicals (Darmstadt, Germany).

Soluble solids were determined in the juice with a refractometer (Kübler, Germany) at 20 °C. The pH juice was measured with a pH meter type MA 5730 (Iskra, Slovenia). The concentration of titrable acids in pears was determined by titration with 0.1 N NaOH with the help of an automatic pipette. An exact amount of pear puree was dissolved with bidistillated water and titrated to the equivalent point at pH 8.1 (*Voi* et al., 1995). Since the pears of cv. 'Williams' contain more citric acid than malic acid (*Hudina & Štampar*, 2000b), titrable acids were not converted into malic acid but were expressed by use of 0.1 N NaOH (ml) at titration. The standard analysis of the main and trace elements in fruits was performed by the Phosyn Laboratories from Great Britain.

The soil was optimally supplied with main and trace elements, there was a bit more of Ca, Mg and Cu (*Table 1*).

Results and discussion

We tried to find out the influence of foliar nutrition on external and internal fruit quality. In the foliar nutrition treatment the diameters of fruits were a little smaller than at the control. The length and the weight of fruits were larger at the foliar nutrition than at the control in the year 1998 (*Table 2*).

The foliar nutrition treatment had a higher content of soluble solids in both years and titrable acids in the year 1998. In the year 1997 titrable acids were the same in both treatments (*Table 3*). The content of acids in pears is low when compared to apples and therefore has less influence on aroma (*Vangdal*, 1982). In pears soluble solids have greater influence on aroma (*Vangdal*, 1985).

Compared to the control, the foliar nutrition treatment increased the content of glucose and sorbitol and lowered the content of fructose and sucrose (*Figure 1*). *Popp & Smirnoff* (1995), *Wang & Stutte* (1992) also stated that with numerous higher plants there is an accumulation of sorbitol during water stress period. The nutrition with potassium (K), incorporated into the foliar fertilizer, increased the concentration of sugars and acids in fruits. This is very

Table 1 Soil analysis in the year 1997. Content of main and trace elements are in mg/kg of soil

Element	pH	Organic Matter	P	K	S	Ca	Mg	B	Cu	Fe	Mn	Mo	Zn
Gudeline level	6.0	3.0 %	26	181	10	1600	120	0.8	2.5	250	120	0.4	5.0
Test level	6.8	4.9 %	20	185	14	6288	416	1.1	20.2	978	268	0.7	7.1
Interpretation	N	N	L	N	N	H	H	N	H	N	N	N	N

N – normal; L – low; H – high

Table 2 Average diameter, length and weight of fruits cv. 'Williams' at different treatments, 1997 and 1998

Treatment	Diameter (mm)		Length (mm)		Weight (g)	
	1997	1998	1997	1998	1997	1998
Control	61.2	69.9	83.5	83.8	145.8	187.8
Foliar nutrition	59.3	69.7	78.3	87.3	131.5	202.3

Table 3 Soluble solids, pH juice and titrable acids in cv. 'Williams' pear fruits at different treatments, 1997 and 1998

Treatment	Soluble solids in %		pH juice		Titrable acid (use of NaOH in ml)	
	1997	1998	1997	1998	1997	1998
Control	12.6	12.6	4.3	4.2	3.2	3.3
Foliar nutrition	13.1	13.1	4.3	4.2	3.2	3.5

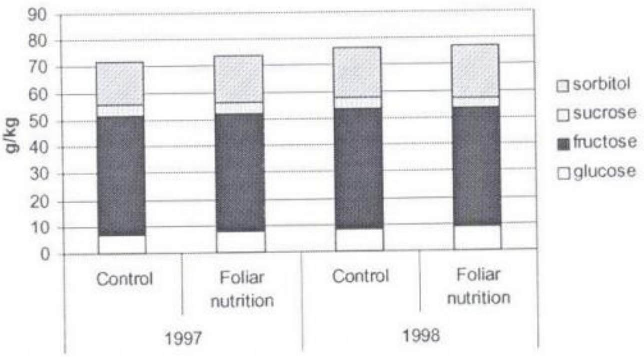

Figure 1 Average content of glucose, fructose, sucrose and sorbitol in g/kg of fresh fruits in pear cv. 'Williams' at different treatments, 1997 and 1998.

favourable for the taste of fruits. The nutrition with potassium (K) helps to increase flower bud differentiation (*Lalatta*, 1975).

Foliar nutrition increased sugars and organic acids in pear fruits. The control treatment had higher content of malic acid in the year 1997, but the content of malic acid was almost one-fold higher than at the control in 1998 (*Figure 2*). This can be explained by the fact that during the nutrition with potassium (K) malic acid is the most represented of all organic acids and it accumulates in the tissues of fruit plants (*Faust*, 1989), but in cv. 'Williams' the most representative organic acid is citric acid (*Hudina & Štampar*, 2000b). Other acids, taking part in Kreks cycle, have minor roll *(Figure 3* and *Figure 4)* in total acidity of pear fruits.

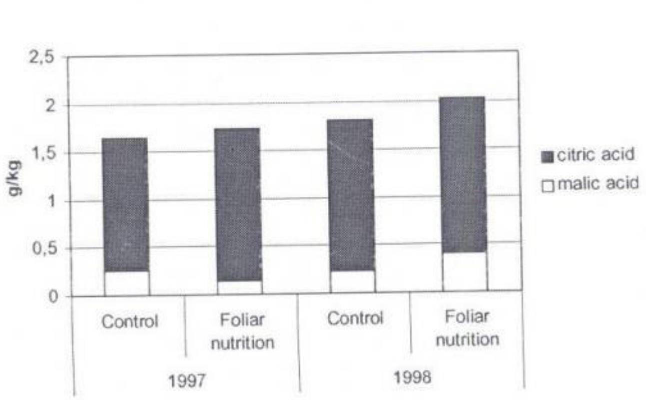

Figure 2 Average contents of malic and citric acids in g/kg of fresh fruits in pear cv. 'Williams' at different treatments, 1997 and 1998.

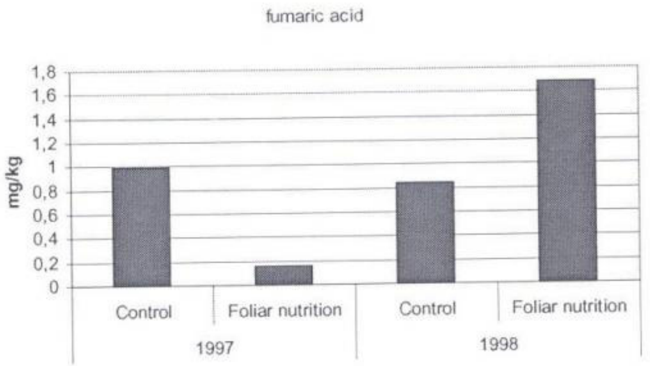

Figure 3 Average contents of fumaric acids in mg/kg of fresh fruits in pear cv. 'Williams' at different treatments, 1997 and 1998.

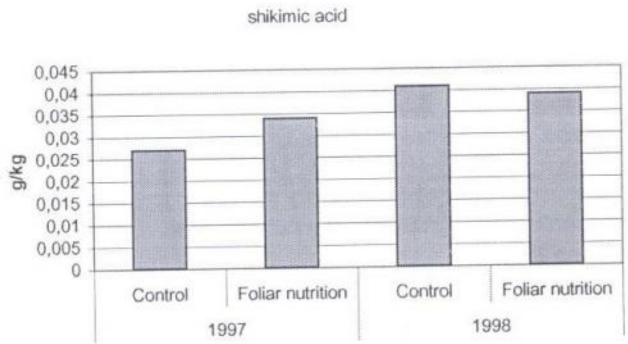

Figure 4 Average contents of shikimic acids in g/kg of fresh fruits in pear cv. 'Williams' at different treatments, 1997 and 1998.

Good indicators of internal fruit quality are also malic/citric and glucose/fructose ratios. At the foliar nutrition the malic/citric ratio and glucose/fructose ratio were higher than at the control, except malic/citric ratio in the year 1997 (*Table 4*). Fructose is the sugar, which contributes most to the fruit sweetness, as it is 1.7-fold sweeter than sucrose. For the best quality of pear fruit glucose/fructose ratio should be about 0.2, what was reached with foliar fertilization.

Table 4 Malic/citric ratio and glucose/fructose ratio in pear cv. 'Williams' at different treatments, 1997 and 1998.

Treatment	Malic/citric ratio		Glucose/fructose ratio	
	1997	1998	1997	1998
Control	0.19	0.15	0.15	0.18
Foliar nutrition	0.09	0.25	0.17	0.19

Both treatments showed lower contents of K and B in the pear fruits in 1997 (*Table 5*). The low K content in fruits can be due to the high Mg concentration in fruits as these two elements are antagonists. The soil also contains a lot of Mg and Ca, what is one of the reasons for small K acceptance. The shortage of B in both treatments influences the metabolism of carbohydrates and suppresses the flow of assimilates from the assimilation centres of photosynthesis. In 1998 there was an insufficiency of K in the fruits as well, although at the treatment of foliar fertilization we sprayed with K and achieved almost optimal amount of K in the fruits. There was too much of Mg at both treatments, that had a negative effect on the acceptance of K into the fruits. The foliar fertilization increased the content of Ca in fruits as well.

Table 5 Contents of main and trace elements (mg/100 g of fruits) in fruits cv. 'Williams' at harvest at different treatments in the years 1997 and 1998.

Element	Optimal contents (Phosyn)	Treatment in year 1997		Treatment in year 1998	
		Control	Foliar fertilization	Control	Foliar fertilization
N	50–70	45.0	45.0	95.0	126.0
P	10–12	13.3	10.5	13.7	15.2
K	100–120	74.0	78.0	89.0	94.0
Ca	>5.0	5.5	4.9	7.4	8.9
Mg	<5.0	5.80	5.00	5.60	6.40
B	0.2–0.6	0.16	0.11	0.23	0.22
Zn	>0.025	0.29	0.24	0.26	0.23

Conclusion

The value of consumed fruit certainly depends on the fruit quality – the internal quality (contents of sugars, organic acids, vitamins, minerals, pectins ...) and the pomological characteristics (shape, fruit colour). The changes of the taste, firmness and appearance of fruits can be the consequence of changes in content and ratio of the organic acids, sugars and alcohols. Sugar and organic acid contents depend on the plant`s genotype and environmental circumstances, which can also be influenced by technological measures such as irrigation, nutrition, assimilation area and training system. The foliar fertilization with P and K in pear fruits of cv. 'Williams' influenced higher quantities of sugars (glucose, sorbitol, soluble solids) and organic acids (malic, citric) and therefore accomplishes better quality of pears. The amount of K increased as well and this leads to better quality and durability of fruits when stored. At the treatment foliar fertilization a trend towards the decrease in the contents of fructose, sucrose, fumaric acid, boron, and zinc was noticed. The foliar fertilization had no effect on the contents of shikimic acid, pH of the juice and titrable acids. The fruits containing high quantities of sugars and organic acids together with the optimal mineral contents are of better internal quality and therefore more suitable for longer storage.

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