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The correlation of the pear (*Pyrus communis* L.) cv. 'Williams' yield quality to the foliar nutrition and water regime

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ABSTRACT

The influence of the foliar nutrition and the water regime on the pear fruits quality (*Pyrus communis* L.) cv. 'Williams' was studied in 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 three treatments: the foliar nutrition, the irrigation and the control. In the treatment of the foliar nutrition the trees were sprayed for 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. In the treatment of irrigation the trees were watered during the growth period with 4 l/tree/day. The foliar nutrition influenced bigger sizes of fruits, increased contents of glucose, sorbitol, soluble solids, malic, citric and fumaric acids, titrable acids and higher pH of juice. The irrigation had influence on the decrease in the contents of individual sugars (glucose, fructose, sucrose, sorbitol), soluble solids, organic acids (malic, citric, fumaric and shikimic) and pH of juice as well as on the bigger sizes of fruits (length, diameter, weight).

Key words: fruit growing, pear, *Pyrus communis*, foliar nutrition, fruit quality, irrigation, organic acids, sugars

IZVLEČEK

ODVISNOST KAKOVOSTI PRIDELKA HRUŠK (*Pyrus communis* L.) SORTE 'VILJAMOVKA' OD FOLIARNE PREHRANE IN PRESKRBE Z VODO

Vpliv foliarne prehrane in preskrbe z vodo na kakovost plodov smo proučevali v plodovih hrušk (*Pyrus communis* L.) sorte 'Viljamovka' v letu 1998. Določali smo vsebnost sladkorjev (glukoze, fruktoze, saharoze in sorbitola) in organskih kislin (jabolčne, citronske, fumarne in šikimske) s pomočjo visokoločljivostne tekočinske kromatografije (HPLC). Plodovom smo izmerili velikost (premer, višina, masa), vsebnost suhe snovi in titrabilnih kislin. V poskus smo vključili 3 obravnavanja: foliarna prehrana, namakano in kontrola. Pri obravnavanju foliarna prehrana smo drevesa 5 krat (od 22. maja do 7. julija) škropili s foliarnim pripravkom Hascon M10 AD, ki je vseboval 15 % P_2O_5, 20 % K_2O, 0,1 % Mn, 0,1 % B in 0,1 % Mo. Pri

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obravnavanju namakano smo drevesa namakali med rastno dobo s 4 l/drevo/dan. Foliarna prehrana je vplivala na večjo velikost plodov, večjo vsebnost fruktoze, sorbitola, suhe snovi, jabolčne, citronske in fumarne kisline, titrabilnih kislin in na večji pH soka. Namakanje je vplivalo na zmanjšanje vsebnosti posameznih sladkorjev (glukoze, fruktoze, saharoze in sorbitola), suhe snovi, organskih kislin (jabolčne, citronske, fumarne in šikimske) in pH soka. Namakanje je imelo pozitiven vpliv na velikost plodov (premer, višina, masa).

Ključne besede: sadjarstvo, hruška, *Pyrus communis*, foliarna prehrana, kakovost plodov, namakanje, organske kisline, sladkorji

INTRODUCTION

In the man's diet fruit is appreciated for the delicious taste, aroma, appearance and the content of nutritive substances, especially vitamins. Sugars, in original forms or as derivatives, and organic acids contribute greatly to the attributes of fruits. Most important for the accumulation of primary and secondary metabolites in fruits, and for the coloration and the resistance of the fruits are the extent of the photosynthesis and the consumption of its metabolites. In the majority of fruit cultivars of the *Rosaceae* family, especially in the genera of *Malus*, *Pyrus* and *Prunus* the main product of the photosynthesis is the alcohol sugar sorbitol which is also the translocating substance (Loescher, 1987). It represents 60 - 90 % of all carbon hydrates, which are transported from the leaves to other parts of the plant. The polyols act as compatible solutes in the leaves, which enable the further course of the photosynthesis and of the metabolism of the carbon hydrates even at less favourable external conditions, for example at water stress (Madore, 1994). Sugars, alcohol sugars, organic acids and vitamins are very useful as indicators of metabolic activities in fruits and they indicate the changes in a qualitative structure of fruits. The variations in taste, firmness and appearance of fruits can be due to the alterations in contents and ratios of organic acids, sugars and alcohols (Doyon *et al*., 1991). The metabolism of cellular contents, important for the taste of fruits (e.g. sugars, organic acids, polysaccharides, pigments and aromatic components) changes significantly during the development of the fruits. So the care for the quality of fruit and yield by metabolic control of these substances during the growth period and during the development of fruits is of special importance.

The content of sugars and organic acids in fruits is connected to technological measures applied in an orchard (training system, nutrition, an assimilation area, irrigation). The water supply during the fruit development has influence on the reception of nutrients into the fruits and also on the content of the individual sugar contents and organic acids in fruits. 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. 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 and Štampar, 2000a).

Our goal in the research work was to establish what influence irrigation and foliar nutrition have on the internal quality of fruit, i.e. on the contents of sugars and organic acids.

MATERIALS AND METHODS

The sugar content (glucose, fructose, sucrose and sorbitol) and organic acids (citric, malic, shikimic and fumaric) were studied from 24 May, 1998 until the harvesting (August 23, 1998) in the cultivar 'Williams' on the quince MA. The experiment encompassed three treatments: irrigation, foliar nutrition and control. At the irrigation treatment the trees were irrigated from 20 May until picking time (23 August) every day with 4 l/tree. 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 in 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). The soil was optimally supplied with nutrients, pH was 6.8. 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 and 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) cartrige (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. 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 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 were the products of Fluka Chemical (New York, NY, USA), except for the malic acid which was a product of Merck Chemicals (Darmstad, 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 and Štampar, 2000b), titrable acids were not converted into malic acid but were expressed by use of 0.1 N NaOH (ml) at titration.

RESULTS AND DISCUSSION

In the experiment we tried to find out what influence the irrigation and foliar nutrition have on external and internal fruit quality. In the foliar nutrition treatment the diameter of a fruit was a little shorter than at the control; the length and the weight of fruits were larger at the foliar nutrition than at the control (Table 1). The foliar nutrition had influence on a higher content of soluble solids and titrable acids (Table 2). 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).

Table 1: Average diameter, length and weight of fruits cv. 'Williams' at different treatments.

Treatment	Diameter (mm)	Length (mm)	Weight (g)
Control	69.9	83.8	187.8
Foliar nutrition	69.7	87.3	202.3
Irrigation	72.8	89.8	231.5

Table 2: Soluble solids, pH juice and titrable acids in pear fruits cv. 'Williams' at different treatments.

Treatment	Soluble solids (%)	pH juice	Titrable acid (use of NaOH in ml)
Control	12.6	4.2	3.3
Foliar nutrition	13.1	4.2	3.5
Irrigation	11.9	4.1	3.3

The irrigation caused the expansion of the sizes of fruits (diameter, length, weight). If the trees are well supplied with water during the growth period, the fruits develop normally. In the last four weeks prior to the picking time the fruits gain to 60 % of their final weight (Caspari *et a*l., 1994). Water stress has a negative impact on the weight of fruits (Behboudian and Lawes, 1994). The fruits from the trees which were irrigated contained less soluble solids, pH juice was also a little lower than at the control (Table 2). Insufficient water supply causes a higher content of soluble solids in fruits (Kilili *et al*., 1996), as during the ripening of fruits starch converts into sugars, the sweetness increases and the taste of fruits (Vangdal, 1985; Wang, 1982).

The fruits of the irrigated trees contained less glucose, fructose, sucrose and sorbitol than at the control (Figure 1). This is supported by the statements of Behboudian and Lawes (1994), who claim that if there is a shortage of water in the last part of the growth period, the content of glucose, fructose, sucrose and sorbitol increases. The water shortage is a stress for a tree. Popp and Smirnoff (1995), Wang and Stutte (1992) also state that with numerous higher plants there is an accumulation of sorbitol during water stress period. Compared to the control, the foliar nutrition influenced a higher content of glucose and sorbitol and lower content of fructose and sucrose. The nutrition with potassium (K) which is incorporated into the foliar fertilizer we employed enables an increase in the concentration of sugars and acids in fruits. This is very favourable for the taste of fruits. The nutrition with potassium (K) helps to increase flower bud differentiation (Lalatta, 1975).

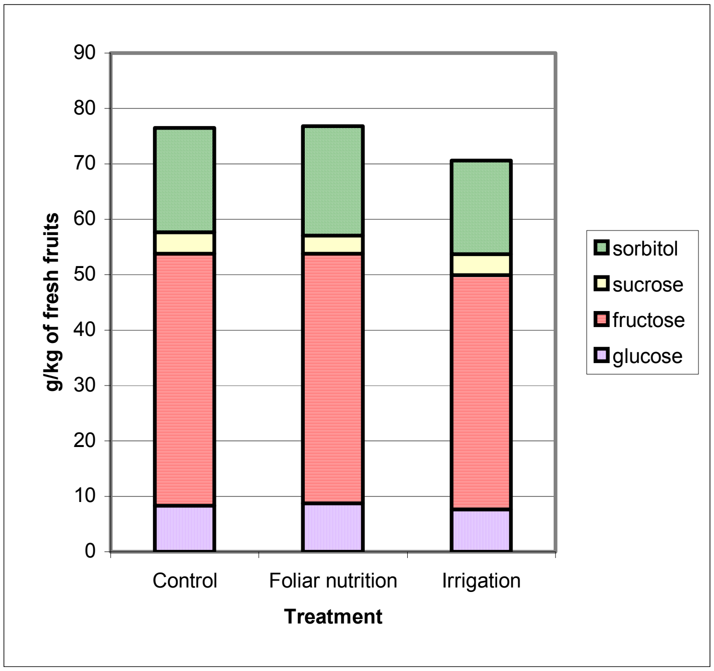

Figure 1: Average content of glucose, fructose, sucrose and sorbitol in g/kg of fresh fruits in pear cv. 'Williams' at different treatments.

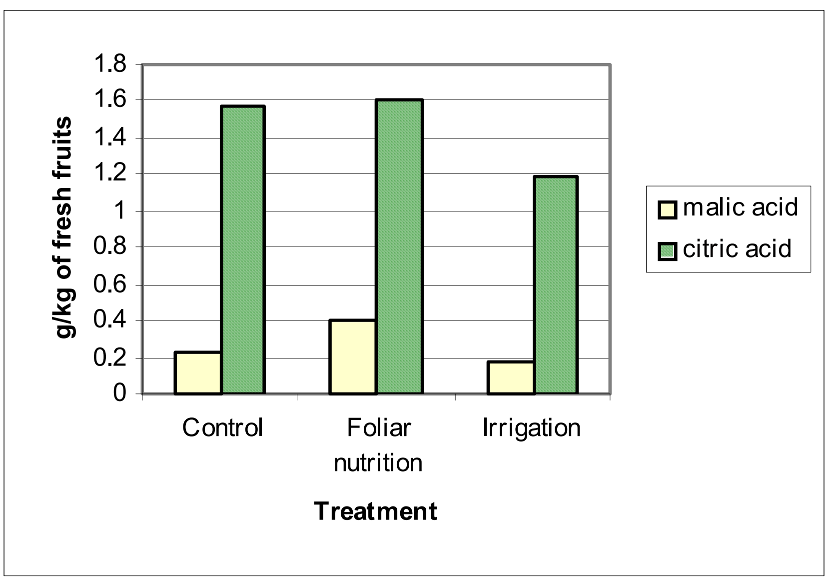

Figure 2: Average contents of malic and citric acids in g/kg of fresh fruits in pear cv. 'Williams' at different treatments.

The irrigation had an impact on lower contents of organic acids (malic, citric, fumaric and shikimic) in pear fruits (Figure 2 and Table 3). The foliar nutrition had influence on the increase of both sugars and organic acids in pear fruits. The content of malic acid was almost one-fold higher than at the control, what can be explained by the fact that during the nutrition with potassium (K) malic acid is most represented of all organic acids and it accumulates in the tissues of fruit plants (Faust, 1989).

Table 3: Average contents of fumaric (mg/g) and shikimic acids (g/kg), malic/citric and glucose/fructose ratio in pear cv. 'Williams' at different treatments.

Treatment	Fumaric acid	Shikimic acid	Malic/citric ratio	Glucose/fructose ratio
Control	0.8	0.04	0.18	0.14
Foliar nutrition	1.7	0.04	0.19	0.25
Irrigation	0.5	0.03	0.18	0.14

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 (Table 3). So the fruits were less sweet and with lower acidity. Fructose is the sugar which contributes the best to the fruit sweetness as it is 1.7-fold sweeter than sucrose. The data on the influence of the irrigation on the fruit quality are contradictory. We discovered that that the irrigation did not have negative influence on external and internal quality of pear fruits. This can be proved by the fact that the malic/citric ratio and glucose/fructose ratio were the same at the irrigation and at the control.

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, size, 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. If the irrigation is carried out at the appropriate time and with optimal quantities of additional water, there is no negative influence on the fruit quality. The fruit quality and storage ability can be improved by the foliar nutrition of trees.

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