Phyton (Austria) Special issue: "Root-soil interactions"	Vol. 40	Fasc. 4	(91)-(96)	25.7.2000

Influence of Water Regimes and Mineral Contents in Soil upon the Contents of Minerals, Sugars and Organic Acids in Pear Fruits (*Pyrus communis* L.) Cv. 'Williams'

By

M. HUDINA[1] & F. ŠTAMPAR[1]

Key words: Pear, *Pyrus communis* L., water stress, mineral contents, sugar, organic acid.

Summary

HUDINA M. & STAMPAR F. 2000. Influence of water regimes and mineral contents in soil upon the contents of minerals, sugars and organic acids in pear fruits (*Pyrus communis* L.) Cv. 'Williams'. - Phyton (Horn, Austria) (40) (4): (91) - (96).

In the years 1997 and 1998 we studied the influence of early and late water stresses, the influence of mineral contents in the soil and their consequences on the contents of sugars (glucose, fructose and sucrose), sorbitol and organic acids (malic, citric, fumaric and shikimic) in the pear fruits of cv. 'Williams'. The contents of sugars and organic acids were determined by HPLC analysis. The experiment encompassed three observations: early water stress (from June the 1st to July the 15th), late water stress (from July the 15th until picking time) and control. The soil was optimally supplied by minerals, there was only a bit more of Ca, Mg and Cu. We stated that troubled water supply in the treatment with late water stress caused smaller admissions of Ca, K and B and higher contents of soluble solids in the fruits, early water stress on the other hand influenced the lower contents of Ca and sucrose in the fruits. Troubled water supply at the beginning and at the end of fruit development (early and late water stresses) influenced a higher content of N in the fruits in the year 1997. In the treatment with early water stress we stated higher contents of K and citric acid than in the control in the year 1997.

[1] Biotechnical Faculty, Agronomy Department, Institute for Fruit Growing, Viticulture and Vegetable Growing, Jamnikarjeva 101, 1000 Ljubljana, Slovenia, e-mail: metka.hudina@bf.uni-lj.si

Introduction

The water supply has influence on the reception of nutrients and their accumulation in fruits. If a plant has enough water at its disposal, the concentrations of P and K in fruits increase, while the concentration of Ca decreases (MARANGONI & PISA 1993). The reception of Ca is influenced by a sufficient supply of carbohydrates to the plant. Similarly, the reception of other nutrients is connected with the intensity of the net photosynthesis (FAUST 1989). The water stress increases the concentrations of sorbitol, glucose and fructose, while the concentrations of sucrose and starch significantly decrease (WANG & STUTTE 1992). The contents of individual sugars, organic acids, main and trace elements in fruits are very important indicators of the inner fruit quality.

Materials and Methods

The sugar content (glucose, fructose and sucrose), sorbitol and organic acids (citric, malic, shikimic and fumaric) were studied during the harvest (August the 17th, 1997 and August the 23rd, 1998) by the cultivar 'Williams'. The experiment encompassed three treatments: early water stress, late water stress and control. Early water and late water stresses were achieved by covering the soil with a plastic foil from June 1 to July 15 and from July 15 to the harvest respectively. There were 12 trees included per treatment (4 blocks with 3 trees per plot). One fruit from each tree was used to determine contents of sugar, sorbitol and organic acids. Samples were prepared firstly by homogenisation 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 minutes (DOLENC & ŠTAMPAR 1997). For each HPLC analysis of sugars, sorbitol and organic acids 20 µl of sample were used. Sugars and sorbitol were analysed in the column Aminex - HPX 87C with flow of 0,6 ml/min and at 85 °C. For mobile phase bidistillated water was used and a RI detector for identification. Organic acids were analysed in the column Aminex - HPX 87H with flow of 0,6 ml/min and at 65 °C. For mobile phase 4 mM sulphuric acid (H_2SO_4) was used together with UV detector with wavelength at 210 nm for identification. Soluble solids were determined in the juice with the refractometer (Kübler) at 20 °C. The titrable acids were determined by titration of the samples with the 0.1 N NaOH to the end point 8.1 and were expressed through the consumption of the NaOH at titration as the cv. 'Williams' contains more citric than malic acid which is the usual way of expressing the titrable acids. Fluka Chemical standards were applied for sugars, sorbitol and organic acids. The standard analysis of the main and the trace elements was performed by the Phosyn Laboratories from Great Britain. The data were analysed by using a completely randomised design as described by SNEDEKOR and COCHRAN 1971.

Results and Discussion

The content of sugars, organic acids, alcoholic sugar sorbitol, main and trace elements in the fruits of the cultivar 'Williams' pear were determined at the picking time (optimal ripening time). The soil was optimally supplied with main and trace elements, there was a bit more of Ca, Mg and Cu (Table 1).

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

In both years, all the treatments showed the low content of K in pear fruits, and in 1997 the low content of B as well (Table 2). 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 contained a lot of Mg and Ca which influenced the small K acceptance. The B deficiency present in all treatments influenced the carbohydrates' metabolism and retained the off-flow of assimilants from the photosynthesis assimilantion centres, as in both treatments when compared to the control less fructose and sucrose in fruits were determined. The Ca content in pear fruits was too low at the late water stress. The consequences of the troubled water supply at the late water stress influenced both a smaller Ca acceptance, although its content in soil is usually too high, and a smaller acceptance of K and B, contents of which in soil are sufficient. The troubled water supply at the beginning as well as at the end of the fruit development influenced a higher N content in fruits in 1997. Early water stress fruits contained more citric acid and more K than the late ones in 1997. FAUST 1989 states that K increases the organic acids content in tissues. In fruit plants the organic acids especially the malic acid were formed. The accumulation of the organic acids is often the consequence of the K^+ transport. In the experiment a higher content of citric and not malic acid was stated. Cv. 'Williams' contains higher amounts of citric than malic acid. This is not expected as it is generally known to appear in fruit plants. In 1997 and 1998 the K content was lower in fruits at both water stresses compared to the control. Mg is active in the photosynthesis and in the mechanisms which influence the tissue resistance to the water deficiency (EBEL & al. 1993). Early and late water stresses have influence on the acceptance of B into the fruits and therefore on the metabolism of the carbohydrates. In the year 1998 in all treatments much higher contents of N and Ca were traced than in the year 1997.

Table 2. Contents of main and trace elements (mg/100 g of fruits) in fruits cv. 'Williams' at different treatments in the years 1997 and 1998.

Element	Optimal contents (Phosyn)	Treatment in year 1997			Treatment in year 1998		
		Control	Early water stress	Late water stress	Control	Early water stress	Late water stress
N	50-70	45.0	64.0	52.0	95.0	91.0	77.0
P	10-12	13.3	11.3	10.1	13.7	12.9	13.3
K	100-120	74.0	75.0	68.0	89.0	87.0	85.0
Ca	>5.0	5.5	5.4	4.4	7.4	6.4	6.8
Mg	<5.0	5.80	5.10	4.90	5.60	6.20	6.10
B	0.2-0.6	0.16	0.15	0.11	0.23	0.18	0.20
Zn	>0.025	0.29	0.29	0.25	0.26	0.26	0.21

The data on changes in the mineral structure are contradictory as always. BEHBOUDIAN & LAWES 1994 stated that the concentrations of N, P, K, Ca and Mg in fruits of the cv. 'Nijisseiki' pears during the early water stress were decreasing. We stated at the early water stress lower contents of P, Ca, B and at the late water stress lower contents of P, K, Ca, B and Zn. CASPARI & al. 1993 stated that at the harvest there are no statistically significant differences in contents of N, P, K, Ca, Mg, Zn and Mn between the control and the water stress. In the experiment in 1998 we found both less Ca in the fruits at the early and the late water stresses and lower contents of glucose, fructose, sucrose and sorbitol than at the control. FAUST 1989 quotes that the acceptance of Ca to the fruits is conditioned by the sufficient supply of the carbohydrates.

In both years the early water stress influenced a lower sucrose content (Fig. 1). The glucose, fructose and sorbitol contents were at the early water stress in 1997 higher than in the control and in 1998 lower than at the control. This can be due to the high rainfall in 1997 after the early water stress treatment. In 1997 the content of soluble solids at early water stress differed statistically significantly from the late water stress content (Fig. 2). There was a significant influence of late water stress on the lower glucose and sucrose contents in 1998 (Fig. 1). The troubled water supply influenced at the beginning as well as at the end of the fruit development both a lower content of shikimic acid and a higher content of titrable acids (NaOH consumption) (Table 3). The early water stress had influence on a lower juice pH, the late water stress on the other hand influenced a higher juice pH. The fruits at the early water stress contained statistically significantly lower amount of shikimic acid compared to the control.

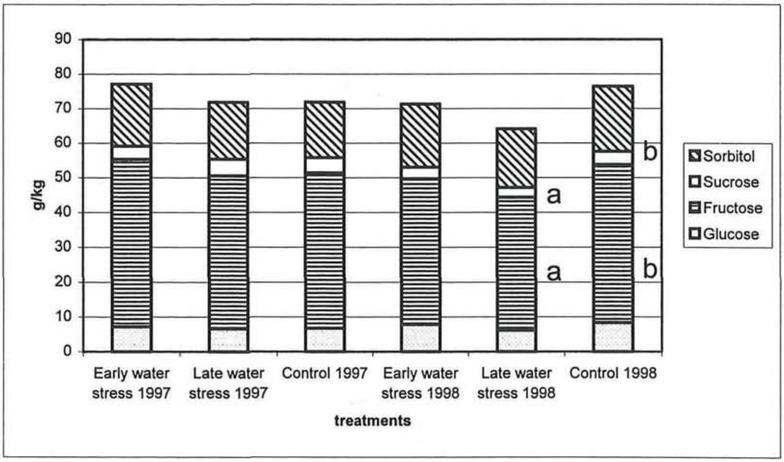

Fig. 1. Average contents of glucose, fructose, sucrose and sorbitol in g/kg of fresh fruits at different treatments in the years 1997 and 1998. Statistically significant differences between treatments are marked with different letter.

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 inner 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.

Table 3. Average contents of malic, citric, shikimic acid in g/kg of fresh fruits, fumaric acid in mg/kg of fresh fruits, titrable acids (use of NaOH in ml), juice pH and LSD values at different treatments in the years 1997 and 1998.

Year	Treatment	Malic	Citric	Fumaric	Shikimic	Titrable acids (use of NaOH in ml)	juice pH
1997	Early water stress	0.16	2.15	0.36	0.03	3.62	4.17
	Late water stress	0.13	1.70	0.16	0.02	3.69	4.39
	Control	0.26	1.39	0.10	0.03	3.26	4.33
	LSD $_{(p=0.05)}$	0.51	1.45	0.42	0.02	0.97	0.40
1998	Early water stress	0.27	1.26	0.44	0.02 a	3.78	4.14
	Late water stress	0.36	1.29	0.81	0.03 ab	3.52	4.26
	Control	0.23	1.58	0.84	0.04 b	3.26	4.20
	LSD $_{(p=0.05)}$	0.87	0.53	0.54	0.012	0.88	0.32

Statistically significant differences between treatments are marked with different letter.

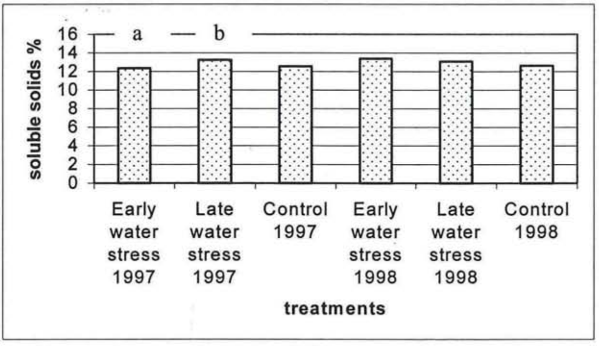

Fig. 2. Average contents of soluble solids in % at different treatments in the years 1997 and 1998. Statistically significant differences between treatments are marked with different letter.

References

BEHBOUDIAN M. H. & LAWES G. S. 1994. Fruit quality in 'Nijisseiki' Asian pear under deficit irrigation: Physical attributes, sugar and mineral content, and development of flesh spot decay.- New Zealand J. of Crop and Hortic. Sci. 4: 393-400.

CASPARI H. W., BEHBOUDIAN M. H., CHALMERS D. J. & RENQUIST A. R. 1993. The pattern of seasonal water use of Asian pears as determined by lysimeters and the heat-pulse technique.- J. Am. Soc. Hort. Sci. 118: 562-569.

DOLENC K. & ŠTAMPAR F. 1997. An investigation of the application and conditions of analyses of HPLC methods for determining sugars and organic acids in fruits.- Research Reports Biotechnical Faculty University of Ljubljana 69: 99-106.

EBEL R. C., POEBSTING E. L. & PATTERSON M. E. 1993. Regulated deficit irrigation may alter apple maturity, quality, and storage life.- HortScience 28: 141-143.

FAUST M. 1989. Physiology of temperate zone fruit trees, 338pp. - New York, John Wiley & Sons.

MARANGONI B. & PISA P. R. 1993. Ricerche sull' efficienza d' uso dell' acqua in arboricoltura.- Frutticoltura 60: 15-18.

SNEDECOR G. W. & COCHRAN W. G. 1971. Statistical methods, pp258 - 298. - Iowa, The Iowa State University press.

WANG Z. & STUTTE G. W. 1992. The role of carbohydrates in active osmotic adjustment in apple under water stress.- J. Amer. Soc. Hort. Sci. 117: 816-823.