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Influence of Water Stress and Assimilation Area on the Sugar Content and Organic Acid during the Growth Period in the Pear fruits (*Pyrus communis* L.) cv. 'Williams'

By

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Summary

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Influence of the early and late water stress and the assimilation area on the sugar content (glucose, fructose and sucrose), sorbitol and organic acids (malic, citric, fumaric and shikimic) and the related changes during the growth period in the pear fruits of cv. 'Williams' was studied in 1997. Sugar and organic acid contents were determined by HPLC analysis. The experiment encompassed four observations: early water stress (from June 1 till July 15), late water stress (from July 15 till August 17), the 30 per cent defoliation (July 22) and control. Water stress and defoliation had no impact either on the diameter, length or weight of fruits, but did influence the sugar and organic acid contents. Late water stress did effect the soluble solids, whereas defoliation had negative effect on the soluble solids content. Early water stress caused the decrease of glucose, fructose, sucrose and sorbitol if compared with control. Glucose content rapidly decreased after defoliation, but oscillated up and down with late water stress, however, it was still lower than that of control.

Introduction

For the accumulation of primary and secondary metabolites in fruits, for the coloration and the resistance of the fruits, the extent of the photosynthesis and

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the consumption of its metabolites are most important. In the majority of fruit cultivars of the *Rosaceae* family, especially in the genera *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 the 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). The malic acid is most frequently present in apples and pears, some cultivars on the other hand contain extensive amounts of citric acid. The metabolism of cellular contents, important for the taste of fruit (for ex. 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.

Material and Methods

The sugar content (glucose, fructose and sucrose), sorbitol and organic acids (citric, malic, shikimic and fumaric) were studied from June 1, 1997 until the harvesting (August 17, 1997) by the cultivar 'Williams' on the quince MA. The experiment encompassed four treatments: early water stress (E) (from June 1 till July 15), late water stress (L) (from July 15 till August 17), the 30 per cent defoliation (D) (July 22) and control (C). Early water stress achieved by covering the ground with black plastic foil from 1st June till 15th July and at late water stress from 15th July till harvesting (17th August). 12 trees were 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 manual blender (Braun), then with Ultra-Turrax T-25 (Ika - Labortechnik). 10 g of mashed fruit was dissolved with bidistillated water up to 40 ml and centrifuged at 6000 rotation/min for 15 minutes. Prior to the injection in the column the samples were filtrated through 0.45 µm Minisart filtre (RC-25, Sartorious). For each HPLC analysis of sugars, sorbitol and organic acids 20 µl of sample were used. The HPLC system of the TSP manufacturer (Thermo Separation Products) was 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 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 and UV detector with wavelength at 210 nm for identification. Soluble solids were determined in the juice with the refractometer (Kübler) at 20 °C. Fluka Chemical (New York, NY, USA) standards were applied for sugars, sorbitol and organic acids.

Results and Discussion

The content of sugars (glucose, fructose and sucrose) and of the alcoholic sugar sorbitol in the fruits of the cultivar 'Williams' pear was determined from fruit set to maturity. In Table 1 are given the average values of glucose, fructose, sucrose and sorbitol at different treatments during the period of growth and the HSD values at $p = 0.05$. The glucose content is decreasing during the development of fruits. A considerable decrease of the glucose is observed at the beginning of

July, it is connected with the starch accumulation, which reaches its climax in August and then decreases again, as stated by BERÜTER 1985. At harvesting there are no characteristic differences among singular treatments and control. At defoliation which was performed on the 27th July 1997 the foliage surface was reduced, so consequently also the net photosynthesis and the result was a lower content of glucose and other sugars. A few days after the defoliation (July 27) a considerable fall in the glucose content was noticed and it was then decreasing until harvesting.

Table 1. Average contents of glucose, fructose, sucrose and sorbitol in g/kg of fresh fruits sampled after different treatments (HSD: $p = 0.05$).

	Treatments	Date of sampling							
		1. 6.	16. 6.	29. 6.	13. 7.	27. 7.	3. 8.	10. 8.	17. 8.
Glucose	C	14.56	15.13	14.99	10.05	9.55	8.45	8.30	6.75ab
	E	13.18	15.33	15.39	8.86	7.04	5.84	7.81	7.17a
	L	13.50	14.99	15.26	10.51	9.04	6.46	7.65	6.61ab
	D	14.69	15.14	15.18	10.78	8.16	7.62	6.79	4.55b
	HSD	2.18	3.71	1.67	4.52	4.92	4.12	2.40	2.52
Fructose	C	15.92	20.10b	31.10	35.80	45.90	43.19ab	53.79	44.63
	E	14.17	18.17a	31.21	32.57	36.26	33.42a	52.38	48.17
	L	15.70	20.50b	32.79	41.06	48.53	42.66ab	56.58	43.95
	D	15.56	20.21b	31.30	39.21	48.30	49.69b	54.04	36.03
	HSD	2.44	2.21	2.67	11.86	14.11	16.04	10.24	19.86
Sucrose	C	0.48	0.00	0.56	2.81	3.51ab	3.12	4.86ab	4.45
	E	0.00	0.00	1.66	2.15	2.56a	2.36	3.71a	3.82
	L	0.50	0.00	1.16	2.99	3.98b	3.73	5.35b	4.83
	D	0.00	0.00	0.00	2.76	3.33ab	4.33	5.41b	3.94
	HSD	1.55	/	1.85	1.74	1.38	2.51	1.58	2.62
Sorbitol	C	31.74	29.90	30.71	23.70	21.51	18.82ab	19.87	16.05
	E	32.52	29.35	32.10	23.68	18.14	15.01a	20.69	17.94
	L	33.48	29.51	30.78	25.82	22.41	19.41ab	21.56	16.47
	D	32.43	28.67	31.06	26.01	24.02	21.43b	20.18	11.86
	HSD	3.58	3.72	3.56	8.13	9.11	6.23	4.46	8.67

Statistically significant differences between treatments were marked with the different letter.

The fructose content evenly increases during the growth period up to the end of July, then decreases slightly, later it increases and decreases again slightly at harvesting. The influence of the early water stress was visible after 16 days (June 16), when the treatment early water stress statistically strongly differed from other treatments. At the late water stress and defoliation in this period we did not take any measures yet, so it is clear that these two treatments at that time equal the control. At subsequent samplings this statistically significant difference at the early water stress diminishes or disappears by the end of July. Until harvesting all differences decrease. The fructose content at defoliation is much lower in comparison with other treatments, what is connected with the above mentioned reduced foliage surface and the net photosynthesis, it shows also in the sucrose and sorbitol content.

The sucrose content increases during the growth period, especially after the June fruit drop it is non-existent at the beginning or is present only in very small quantities. At defoliation treatment there was no trace of sucrose until the middle of July. The early water stress influenced the decrease of sucrose content.

Table 2. Average contents of malic, citric, shikimic acid in g/kg and fumaric acid in mg/kg of fresh fruits sampled after different treatments (HSD: p = 0.05).

	Treatments	Date of sampling							
		1. 6.	16. 6.	29. 6.	13. 7.	27. 7.	3. 8.	10. 8.	17. 8.
Malic	C	3.13	3.60	3.51	1.90	0.26	0.31	0.23	0.26
acid	E	2.60	3.67	4.48	1.97	0.67	0.62	0.03	0.16
	L	2.56	3.45	3.13	1.32	0.00	0.69	0.66	0.13
	D	2.97	3.07	3.40	0.81	0.00	0.00	0.00	0.53
	HSD	1.62	1.05	1.95	2.19	0.73	0.88	1.07	0.77
Citric	C	4.04	2.67	0.29	0.90	1.39	1.18	1.91	1.39
acid	E	2.84	2.19	0.59	1.08	1.10	0.85	2.49	2.15
	L	2.98	2.23	0.29	0.85	0.97	1.38	2.43	1.70
	D	2.88	1.96	0.27	0.67	0.99	2.15	2.17	1.09
	HSD	4.68	1.48	0.41	1.31	0.87	1.33	1.68	1.57
Shikimic	C	0.34	0.32	0.24	0.09	0.06	0.04	0.04	0.03
acid	E	0.27	0.29	0.28	0.10	0.04	0.03	0.05	0.03
	L	0.38	0.33	0.24	0.10	0.07	0.04	0.04	0.02
	D	0.33	0.30	0.25	0.10	0.07	0.06	0.06	0.02
Fumaric	C	11.79	3.49	3.86	0.86	0.80	0.38	0.47	0.10
acid	E	16.90	5.23	8.42	1.37	0.62	0.33	0.72	0.36
	L	12.23	5.28	2.56	1.52	2.50	0.08	0.62	0.16
	D	14.99	4.18	8.04	1.14	1.96	0.70	0.80	0.08

Statistically significant differences between treatments were marked with the different letter.

The sorbitol content diminishes with the development of fruits. The higher content of sorbitol can be influenced by the stress factors such as defoliation, what was visible also in our experiment, showing statistically significant differences between the early water stress and the defoliation at the beginning of August (August 3), later this difference lessens. At the control on August 10 the sorbitol content was the lowest in comparison with other treatments, although the difference was not statistically significant. But the strong fall of sorbitol at harvesting after the defoliation treatment is not understandable.

In the Table 2 are given the average contents of malic, citric, shikimic and fumaric acids after the treatments during the growth period. The malic and citric acids, other organic acids (quinic, shikimic, fumaric) in smaller quantities (ARFAIOLI & BOSETTO 1993) are most frequently present in pears. In the ripe cultivar 'Williams' fruits the citric acid is prevalent. There is much less malic acid present. The consequence of the defoliation was the strong decrease of the malic acid content, even a total absence was noticed in the fruits after the defoliation till harvesting. At harvesting the content of the malic acid at defoliation was the highest compared to other treatments. The content of the citric acid was diminishing until the end of the June fruit drop, later it was increasing again. The content of the soluble solids was highest at harvesting at the treatment late water stress (13.24 %), followed by control (12.55 %), early water stress (12.36 %) and defoliation (11.57 %).

Water stress and defoliation had no impact either on the diameter, length or weight of fruits, but did influence the sugar and organic acid contents. Late water stress did effect the soluble solids, whereas defoliation had negative effect on the soluble solids content. Early water stress caused the decrease of glucose, fructose, sucrose and sorbitol if compared with control. Glucose content rapidly decreased after defoliation, but oscillated up and down with late water stress, however, it was still lower than that of control.

Defoliation, which can be caused by diseases, pests or heat, and water stress destroy the sugar acid ratio. A balanced sugar acid ratio is namely responsible for harmonious taste of pears. Water supply during slow and fast fruit growth also have an influence on fruit quality.

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