Journal of Elementology ISSN 1644-2296

Jaroszewska A., Kowalewska R. 2016. *Chemical composition of cherry fruit from the cultivars Kelleris 16 and Łutówka depending on different water conditions and fertilization*. J. Elem., 21(1): 43-52. DOI: 10.5601/jelem.2015.20.1.885

CHEMICAL COMPOSITION OF CHERRY FRUIT FROM THE CULTIVARS KELLERIS 16 AND ŁUTÓWKA DEPENDING ON DIFFERENT WATER CONDITIONS AND FERTILIZATION

Anna Jaroszewska, Róża Kowalewska

Chair of Agronomy
West Pomeranian University of Technology in Szczecin

Abstract

The research was conducted in 2011-2012, at the Experimental Station in Lipnik near Stargard Szczeciński, on soil classified as Haplic Cambisol, with low useful water retention. The experiment was designed with a split-plot method and repeated seven times. Grass cover was maintained in the row middles while the area underneath the trees was kept as herbicide fallow. The trees were planted in 4x2 m spacing. The assessment concerned the influence of irrigation and NK fertilisation on the dry matter and chemical composition of cherry fruit from the cultivars Kelleris 16 and Łutówka. Micro-irrigation was used at water potential in soil lower than 0.01 MPa. According to agronomic recommendations, nitrogen fertilizers were applied in early spring and potassium fertilizers in autumn in the following doses: 0 NK (control, no fertilization), 1 NK – 80 kg ha^{-1} (40+40), 2 NK – 160 kg ha^{-1} (80+80), according to agronomic recommendations. Ammonium nitrate containing 34% of nitrogen and potash salt containing 60% of potassium were used for fertilization. Observations of the irrigated trees showed an increase in the dry mass in their fruit, as well as a decrease in nitrogen, potassium and magnesium concentrations, but an increase in the amount of calcium. Chemical analyses of the fruit harvested from the trees fertilized with nitrogen and potassium demonstrated an increase in the analysed traits (macro- and micronutrients), at both 1NK and 2NK fertilization levels.

Keywords: irrigation, fertilization, macro- and microelements, dry mass, cultivars.

dr inż. Anna Jaroszewska, Chair of Agronomy, West Pomeranian Technological University, Słowackiego 17, 71-424 Szczecin, Poland, e-mail: anna.jaroszewska@zut.edu.pl

INTRODUCTION

Because of their valuable nutritional and health properties, cherries are mainly grown for the food industry. They have anti-inflammatory properties and reduce the risk of atherosclerosis and heart diseases. Cherries can be consumed raw or in desserts, but they can also be processed into preserves, dried, candied or frozen.

In Poland, cherries hold a very important position in fruit production. In terms of the production volume, cherries rank as the second or third most commonly processed fruit on the market, after apples and strawberries (Brzozowski, Klimek 2010).

According to the Main Statistical Office, cherry harvests in 2011 and 2012 reached approximately 175 thousand decitonnes, and the yields could have been even higher if not for the shortage of precipitation, which caused diminution of the fruit (www.stat.gov.pl).

Plant production is proportional to water usage. Whenever there is water shortage, transpiration decreases and photosynthesis is less efficient, hence a decrease in biomass production. In view of this dependency, it is generally accepted that the maximum crop production is obtained by minimizing the plant water deficit throughout the development of the crop (Chalmers et al. 1985). In turn, the commercially valuable impact of calcium on the quality of fruits during storage encourages further studies to find the most adequate N/Ca and K/Ca ratios (Pacheco et al 2008). Although the effects of irrigation and mineral fertilization on the quality of fruit have been discussed rather extensively in literature (Koo 1980, Nava et al. 2007, Amiri et al. 2008, Ochmian 2012, Szot, Lipa 2012, Ochmian, Kozos 2015), the information about the specific influence of these treatments on the chemical composition of cherry fruit is scarce (Podsiadło et al. 2009).

The aim of this research was to assess the influence of irrigation as well as nitrogen and potassium fertilisation on the dry mass and levels of selected macro- and microelements in the cherry fruit.

MATERIAL AND METHODS

The study was conducted on fruit from cherry trees of the cultivars Kelleris 16 and Łutówka budded on mahaleb cherry seedlings. The soil on which the trees grew belonged to proper typical rusty soils (Polish Soils Systematics 2011) and was classified as Haplic Cambisol (IUSS Working Group WRB 2014). In the Ap horizon, the texture composition corresponded to clay sand with slightly acidic pH, some humus content (1.3-1.5%) and floating particles (11-13%). The humus level was formed from clay sands. The the soil mineral content analysis showed high levels of phosphorus and moderate levels of magnesium and potassium.

The study was conducted in 2011-2012, at the Experimental Station in Lipnik near Stargard Szczeciński (53°20′35″N 14°58′10″E). The experiment was designed with a split-plot method and repeated seven times (one tree each time). The research was carried out on trees in their 13th and 14th year after planting. Grass cover was maintained in the row middles while the area underneath the trees was kept as herbicide fallow. The trees were planted in 4x2 m spacing. The design of the experiment consisted of two factors. The primary factor was microirrigation: O – controlled objects with no irrigation, W – irrigated objects. The irrigation was started when the potential of water in the soil fell below -0.01MPa. The irrigation doses and timing were determined according to the readings on tensiometers installed 20 cm below the soil surface. Hadar micro-sprinklers used for watering ensured a sprinkler range of r = 1 m and efficiency of 2.5 l h^{-1}. One sprinkler was used for each tree. The amount of water applied to the trees was 33.8 mm ha^{-1} in 2011 and 36.3 mm ha^{-1} in 2012 (i.e. 0.27 and 0.29 m^3 per tree, respectively), depending on the amount of precipitation in a given period of study.

The secondary factor was nitrogen and potassium fertilization: 0 NK (control, no fertilization), 1 NK – 80 kg ha^{-1} (40+40), 2 NK – 160 kg ha^{-1} (80+80). Nitrogen fertilizers were applied in early spring and potassium fertilizers were supplied in autumn, according to agronomic recommendations. Ammonium nitrate containing 34% of N and potash salt containing 60% of K were used for fertilization. Foliar fertilization and chemical plants protection treatments were not applied.

The atmospheric conditions during the investigations are presented in Table 1. The years in which the research was conducted were warmer than the multiyear average by 1.4°C. Precipitation was comparable to the multiyear average.

Fruit harvesting took place on 28th June (Kelleris 16) and 13th July (Łutówka) in 2011, and on 2nd July (Kelleris 16) and 18th July (Łutówka) in 2012. A cumulative sample of 2 kg was collected from each experimental

Table 1

Mean air temperature (°C) and sum of rainfall (mm) during the experiment as compared with multiyear average

Month	Multiyear average (1964-1991)		Rain (mm)		Temperature (°C)	
	rain (mm)	temperature (°C)	2011	2012	2011	2012
IV	37.8	7.2	11.6	23.4	11.4	8.3
V	51.1	12.5	28.0	18.4	14.1	14.1
VI	61.3	15.9	32.3	31.2	17.5	15.5
VII	63.2	17.4	150.5	111.3	17.4	18.2
VIII	56.1	17.0	40.5	94.2	18.0	17.7
IX	46.8	13.2	56.1	20.0	15.0	14.3
IV-IX	316.3	13.8	319.0	298.5	15.6	14.7

plot. The samples were dried at 105°C in an oven equipped with a fan. The material was digested in concentrated H_2SO_4 and $HClO_4$ acids for the macronutrient concentration analyses, and in an HNO_3 and $HClO_4$ mixture for micronutrient concentration analyses. The dry mass content was determined using the weight method. Total N concentration was determined by the Kiejdahl destillation method using a Gerhardt 30, while P was assessed by the colourimetric method on a Specol 221 apparatus. An atomic absorption spectrometer (iCE 3000 Series, Thermo Fisher Scientific) was used to determine K. Calcium was determined by means of emulsion flame spectroscopy, whereas the concentrations of Mg, Fe and Zn were detected by absorption flame spectroscopy (IUNG 1972).

The results of the analyses concerning the content of dry matter as well as macro- and micronutrients in the cherry fruit were processed statistically with variance analysis for long-term experiments, whilst the significance of differences with LSD 0.05 was evaluated with the Tuckey's test. All statistical calculations were supported by ANALWAR-5.1.FR software. The correlation analysis of the features that significantly differentiated the interaction of the experimental factors was performed using Statistica v.10.

RESULTS AND DISCUSSION

According to Santos et al. (2007), Ozden et al. (2010) and Tavarini et al. (2011), good water management is fundamental to the optimal growth and crop yield of fruit plants. Fertilization is another significant factor that determines both crop yield and quality of fruits (Zydlik, Pacholak 1999, Sarker, Rahim 2012, Lipa, Szot 2013).

Our results show that both irrigation and mineral fertilization have significant influence on the dry mass content as well as on macro- and micronutrients in the cherry fruit of cv. Kelleris 16 and Łutówka (Tables 2-5).

Table 2

Content of dry matter in cherry fruit cv. Kelleris 16 and Łutówka

Treatment		Years			
		2011		2012	
		Kelleris 16	Łutówka	Kelleris 16	Łutówka
		(%)		(%)	
Irrigation	O	13.5	10.3	12.0	11.9
	W	13.6	12.8	11.6	12.9
Fertilization	0	14,5	10.9	11.7	12.8
	1	12.9	11.9	12.0	12.1
	2	13.2	11.9	11.8	12.2
$NIR_{0.05}$	irrigation	n.s.	n.s.	n.s.	n.s.
	fertilization	n.s.	n.s	n.s	n.s

Table 3

Content of selected macronutrients in the dry matter of cherry cv. Kelleris 16

Treatment		Years									
		2011					2012				
		N	P	K	Ca	Mg	N	P	K	Ca	Mg
		(g kg^{-1} d.m)				(g kg^{-1} d.m)					
Irrigation	O	7.18	1.79	14.9	1.17	1.10	8.89	4.25	22.5	2.56	2.31
	W	6.60	1.93	14.9	0.85	0.90	7.72	3.04	22.7	2.61	1.19
Fertilization	0	6.33	1.64	13.6	1.03	1.02	7.42	3.03	22.9	2.63	1.27
	1	7.07	2.06	15.7	1.12	1.00	6.68	3.03	21.0	2.52	1.10
	2	7.27	1.89	15.7	0.88	0.99	10.8	4.88	24.5	2.61	2.87
NIR $_{0.05}$	irrigation	0.07	n.s.	n.s.	0.06	n.s.	0.59	0.26	0.16	n.s.	2.60
	fertilization	0.66	0.06	0.10	0.04	n.s.	1.66	0.15	0.03	0.04	2.87

n.s. – not significant

Table 4

Content of selected macronutrients in the dry matter of cherry cv. Łutówka

Treatment		Years									
		2011					2012				
		N	P	K	Ca	Mg	N	P	K	Ca	Mg
		(g kg^{-1} d.m)					(g kg^{-1} d.m)				
Irrigation	O	5.20	1.79	15.6	0.63	8.38	4.13	2.10	19.4	2.48	0.87
	W	4.85	1.85	15.0	0.69	8.33	2.29	2.09	18.9	2.63	0.86
Fertilization	0	3.78	1.83	14.6	0.63	8.14	3.15	2.02	18.2	2.46	0.82
	1	5.25	1.73	15.4	0.69	8.11	3.15	2.09	19.3	2.54	0.84
	2	6.05	1.89	16.0	0.66	8.82	3.33	2.16	20.0	2.66	0.94
NIR $_{0.05}$	irrigation	0.29	n.s.	0.46	n.s.	2.15	0.05	n.s.	0.04	0.10	n.s.
	fertilization	1.03	0.06	0.24	n.s.	8.79	n.s	0.08	0.04	0.03	0.01

n.s. – not significant

The dry mass content reflects the concentration of nutritional components in a fruit, which determines its nutritional value and flavour. Apart from species-specific characteristics, the chemical composition of a fresh fruit may vary significantly depending on a cultivar, degree of fruit ripeness or storage conditions (KICZOROWSKA et al. 2006). Although no statistically significant influence of the examined factors on the dry matter content was proven by this research, a tendency of the dry matter content to increase in a fruit grown on irrigated plots was demonstrated (Table 2). This observation finds support in the research of CHEŁPIŃSKI et al. (2009*a*) and SOTIROPOULOS et al. (2010) on peach plants, and the investigations on cherry plants reported by PODSIADŁO et al. (2009) and JAROSZEWSKA (2011). The authors did not determine any significant influence of irrigation or fertilization on the dry mass content in the fruits. According to MAHHOU et al. (2006), water stress reduces

Table 5

Content of selected micronutrients in the dry matter of cherry fruit from cv. Kelleris 16 and Łutówka

Treatment		Years			
		2011		2012	
		Fe	Zn	Fe	Zn
		(mg kg^{-1} d.m)		(mg kg^{-1} d.m)	
		Kelleris 16			
Irrigation	O W	92.09 75.43	9.567 8.915	92.74 42.75	11.54 8.553
Fertilization	0 1 2	96.27 73.13 81.88	9.228 9.140 9.355	94.98 44.03 64.23	10.53 8.838 10.78
NIR $_{0.05}$	irrigation fertilization	12.42 10.41	0.614 0.156	1.017 0.446	n.s. 0.760
Łutówka					
Irrigation	O W	51.25 40.00	9.429 9.067	31.13 29.14	7.537 9.195
Fertilization	0 1 2	31.87 42.50 62.5	7.898 9.897 9.948	25.92 36.93 27.57	8.598 8.123 8.378
NIR $_{0.05}$	irrigation fertilization	5.29 8.13	0.080 0.069	0.499 0.227	0.106 0.077

n.s. – not significant

fresh fruit mass and fresh fruit yield but not the dry mass or dry yield from a fruit.

Many researchers emphasise significant differences in the concentration of macronutrients in irrigated plants. Some observe an increase or a decrease in that property, while others notice no changes at all. Such discrepancies are suggested to arise from the differences in agronomic treatments, plant age or species.

Numerous studies on the nitrogen content in fruits reveal a decrease in the concentration of this element when fruit plants are subjected to supplementary irrigation (RZEKANOWSKI, ROLBIECKI 1996, PODSIADŁO, JAROSZEWSKA 2013).

The current results show a lower content of nitrogen in the fruit harvested from the irrigated trees than from the control plots (non-irrigated). During the first year, the nitrogen content in the fruit was 8% lower for both cultivars (cv. Kelleris 16 and Łutówka), while decreasing decreased by 13% (cv. Kelleris) and 45% (cv. Łutówka) in the second year (Tables 3-4). Phosphorus is another element that determines the quality of a fruit. Harvesting small and sour fruits may be a result of low potassium concentrations. Low levels of calcium, the second element to potassium that is most intensively uptaken, is a frequent cause of physiological diseases. Its low content in fruits causes inferior storage capacity, shrinking and increased acidity of fruits. This study showed that fruit from the irrigated cv. Kelleris 16 trees had a lower calcium content (by 27%) in the first year and a lower phosphorus and magnesium content in the second year (by 28% and 48%, respectively). The fruit harvested from cv. Łutówka grown in the irrigated plots had lower potassium and magnesium concentrations in the first year (by 4% and 1%, respectively). During the second year, a lower potassium content (by 3%) and a higher calcium content (by 6%) were observed in the fruit harvested from the control plots (Tables 3-4). These results may indicate a certain trend (a response characteristic for this species to supplementary irrigation), which finds partial confirmation in the studies of Podsiadło et al. (2009) and Jaroszewska (2011). The analysis of the results also demonstrated a lower concentration of micronutrients (Fe, Zn) in the fruit of the irrigated cv. Kelleris 16 cherry trees in comparison to the fruit gathered from the control trees (non-irrigated). In the case of cv. Łutówka, the zinc content in the second year was 22% higher on the irrigated plots (Table 5).

The application of nitrogen and potassium fertilizers significantly differentiated the content of the analysed macro- and micronutrients in the cherry fruit (Tables 3-4). Referring the responses of both cultivars to the applied fertilization agent, it may be concluded that cv. Łutówka showed a higher increase in the concentration of macronutrients in its fruit. Fertilisation caused an increase in the amount of nitrogen, phosphorus, potassium, calcium and magnesium. However, there was an exception. In 2011, the phosphorus content in the plants fertilised with 1NK was 6% lower than in the control objects. Nitrogen, phosphorus and potassium concentrations in the first year increased in the Kelleris 16 cultivar following the application of the fertilizer (80 kg ha^{-1} and 160 kg ha^{-1}). In the second year, increased concentrations of nitrogen, phosphorus, potassium and magnesium were observed (by 46%, 61%, 7%, 25%, respectively) at the 2NK fertilization level (Tables 3-4). The concentration of micronutrients in the fruit of trees fertilized with 80 kg ha^{-1} and 160 kg ha^{-1} doses increased only in cv. Łutówka in the first year. The levels of Fe increased by 33% and 96%, whilst the levels of zinc rose by 25% and 26%, respectively, in relation to the control objects. Fertilization at 1 NK and 2NK increased the iron content by 42% and 6%, respectively, in the second year (Table 5). The results presented above are to some extent confirmed by Chełpiński et al. (2009*c*), who found a significant effect of fertilization on the increase of calcium and the accumulation of microelements in the pear tree fruit. Also, in the research conducted on apple trees, fertilization resulted in an increased calcium content (Chełpiński et al. 2009*b*), while having no effect on the amounts of dry mass, nitrogen, nitrates, phosphorus, potassium, magnesium or cadmium. According to Stampar et al. (1999), complex foliar fertilization had a positive impact on the quantity and quality of fruits in different apple tree cultivars. In turn, Ochmian et al. (2006) demonstrated that fertilization (N) had no impact on the nitrogen content, although when applied in combination with irrigation, it increased the nitrogen, phosphorus and magnesium content in the fruit of the analysed apple tree cultivar.

Furthermore, the analysis of our research results revealed a negative, highly significant correlation between the magnesium, calcium and zinc content and supplementary irrigation in the case of cv. Kelleris 16 fruit. In the fruit of cv. Łutówka, a strong correlation was detected between the nitrogen concentration and irrigation as well as a positive, highly significant correlation between the zinc content and irrigation. In the same plants, a positive, highly significant correlation was found between nitrogen, phosphorus, potassium, zinc and iron concentrations, and N and K fertilization (Table 6).

Table 6

Correlation between the concentration of macro- and micronutrients in fruit (*x*) of cherry cv. Kelleris 16 and Łutówka and irrigation or fertilization (*y*)

Specification *Y*	*X*	Kelleris 16					
Irrigation	N	P	K	Mg	Ca	Zn	Fe
2011year	-0.581	0.333	-0.013	**-0.861***	**-0.847**	-0.646	-0.187
2012 year	-0.209	-0.427	-0.053	-0.445	0.191	**-0.823**	-0.640
Fertilization	N	P	K	Mg	Ca	Zn	Fe
2011 year	0.769	0.503	0.589	-0.152	-0.316	0.106	-0.131
2012 year	0.498	0.534	0.336	0.518	-0.038	0.056	-0.322
Łutówka							
Irrigation	N	P	K	Mg	Ca	Zn	Fe
2011 year	-0.166	0.237	-0.397	-0.027	0.425	-0.177	0.136
2012 year	**-0.922**	-0.069	-0.333	-0.073	0.596	**0.956**	-0.151
Fertilization	N	P	K	Mg	Ca	Zn	Fe
2011 year	**0.879**	0.219	**0.892**	0.798	0.219	**0.819**	**0.888**
2012 year	0.071	**0.864**	**0.928**	0.719	0.633	-0.103	0.103

* (figures in bold) significant

CONCLUSIONS

The experiment demonstrated a significant influence of the applied agronomic treatments on the values of the analysed traits. Both cherry cultivars produced a similar response to the irrigation, including an increase in dry matter as well as a decrease in nitrogen, potassium, magnesium and calcium concentrations, which may indicate the species-specific response to supplementary irrigation. In turn, the results concerning nitrogen and potassium fertilization indicated an increase in the analysed traits (macro- and micronutrients) at both 1NK and 2NK fertilization levels. In the future, a more thorough identification of this species' response to the application of supplementary irrigation and mineral fertilization may facilitate the control of the cherry fruit quality, including storage capacity or flavour. Therefore, the presented research needs to be continued.

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