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COMPARISON OF THREE SOUR CHERRY CULTIVARS GROWN IN CENTRAL-EASTERN POLAND

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ABSTRACT

Sour cherry is one of the most important fruit crops in Poland and cultivar is an important factor in its cultivation. The experiment was conducted in a commercial family orchard in a year characterized by a warm and wet spring and also by a very hot and dry summer. Fruit yields harvested from well fertilized 19-years old 'Kelleris 16', 'Nefris' and 'Łutówka' trees grafted on Mahaleb cherry and protected against pests using integrated plant protection system were medium high and of good quality, however productivity index of a tree was low. The fruits attained high weight and diameter and contained big amounts of sugars, vit. C, anthocyanins and flavonoids and medium amount of phenolic acids. Among anthocyanins the most important were cyanidin 3-glucosyl-rutinoside and cyanidin 3-rutinoside. Antioxidant activity of fruits measured as percent of DPPH inhibition was high and similar among compared cultivars. Łutówka was the most productive cultivar of medium leaf and fruit size and with fruits of highest vit. C and flavonoids content and lowest total sugars and monosaccharides content. The least productive cultivar was Nefris, though its fruits were the biggest and contained dry matter, soluble solids, anthocyanins and phenolic acids in the highest amounts of all and vit. C at the lowest level of all. Kelleris 16 was the medium productive cultivar characterized by widest leaf blades and smallest fruits. Content of total sugars and monosaccharides in its fruits was the highest and content of anthocyanins and phenolic acids was the lowest. Residues of dodine and thiacloprid determined in the fruits immediately after harvest were much lower than the permissible residue maximum level.

Key words: productivity index, dry matter, anthocyanins, DPPH, dodine, thiacloprid

INTRODUCTION

Among fruit trees grown in Poland, sour cherry has second place after apple in regard to the number of trees and quantity of fruit production and Lublin voivodship (central-eastern part of the country) is an important region of its cultivation [Grzyb and Rozpara 2009]. In 2015 in Poland, total area of sour cherry orchards amounted to 29 311 ha and 4530 ha of this was placed in Lublin voivodship [Rocznik Statystyczny… 2016].

According to Kunachowicz et al. [2017], 100 g of fresh sour cherry fruit contain 12.7 g of dry matter, 12 mg of vit. C, 10.9 g of total carbohydrates, 9.9 g of assimilable carbohydrates with 4.6 g of glucose, 3.9 g of fructose, 0.4 g of saccharose, and 1.0 g of dietary fiber. Grzyb and Rozpara [2009] stated a wide content range of sour cherries major components in 100 g fresh fruits: 11–22% of dry matter, 6–15% of sugars, 0.5–1.8% of organic acids, and 2.5–21.4 mg of vit. C.

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In the studies curried out by Podsiadło et al. [2009], the fruits of Kelleris 16 and Łutówka cultivars contained 7.5% of sugars and 3.72 mg of vit. C in 100 g fresh fruits on an average. The authors observed a tendency to decrease the content of sugars and vit. C in consequence of irrigation. In the experiment curried out by Jadczuk-Tobiasz and Bednarski [2007], the weight of 'Łutówka IR-2' fruit ranged from 4.19 to 4.70 g and the content of soluble solids ranged from 15.2 to 15.9% in dependence on the year. In the study conducted by Selwa et al. [1994], an average 'Łutówka' fruit weight ranged from 3.4 to 3.8 g and content of dry matter ranged from 15.8 to 16.7% in dependence on the rootstock. In other studies an average fruit weight of 'Łutówka' ranged from 3.51 to 5.70 g [Czynczyk et al. 1988, Grzyb et al. 1992/93, Wociór and Kaca 2006, Wociór et al. 2008, Głowacka and Rozpara 2010] and fruit weight of 'Nefris' ranged from 3.32 to 4.71 g [Czynczyk et al. 1988, Grzyb et al. 1992/93] in dependence on the rootstock and/or place and year of study. Fruits of Hungarian sour cherry eleven genotypes contained from 14.4 to 23.1% of soluble solids, from 6.06 to 9.08 g of glucose · 100 g f.w.$^{-1}$, from 3.54 to 4.91 g of fructose · 100 g f.w.$^{-1}$ and about 3.0 to 9.0 mg of vit. C · 100 g f.w.$^{-1}$. Their fruit weight ranged from 3.40 g to 7.17 g [Papp et al. 2010]. Fruits of two Serbian sour cherry cultivars contained 16.25–16.80% of soluble solids, their weight at commercial ripening stage ranged from 2.66 to 3.48 g and their diameter ranged from 15.46 to 15.93 mm [Milošević and Milošević 2011].

In the horticultural practice, productivity of single tree and tree productivity index are important sour cherry varietal attributes which change with the time [Czynczyk et al. 1988, Grzyb et al. 1992/93, Selwa et al. 1994, Wociór and Kaca 2006, Wociór et al. 2008, Jadczuk-Tobiasz and Bednarski 2007, Głowacka and Rozpara 2010]. Majority of cited above authors measured these parameters on young trees. Wociór and Kaca [2006] harvested in dependence on rootstock from 34.7 to 37.6 kg of fruits from one 12-years old 'Łutówka' tree. Wociór et al. [2008] harvested 33.3 and 35.0 kg of fruits from one 10- and 11-years old 'Łutówka' tree grafted on Mahaleb cherry respectively. In two other studies accomplished in Poland on 10-years old 'Łutówka' and 'Nefris' trees, a productivity index ranged in dependence on rootstock from 1.60 to 1.86 kg·cm^{-2} and from 1.38 to 1.49 kg·cm^{-2} [Czynczyk et al. 1988] and from 0.74 to 1.16 kg·cm^{-2} and from 0.73 to 1.18 kg·cm^{-2} respectively [Grzyb et al. 1992/93].

Cherries are the source of natural antioxidants and among them phenolic compounds (anthocyanins, flavonoids, phenolic acids) and ascorbic acid [Velioglu et al. 1998, Veres et al. 2008]. Fruits of 'Montmorency' sour cherry grown in Oregon, USA, contained 14.43 % of soluble solids, 407 mg of total phenolics and 8.7 mg of total anthocyanins in 100 g of edible portion [Chaovanalikit and Wrolstad 2004]. Fruits of four sour cherries cultivars picked at commercial maturity in New York state contained from 146.1 to 312.4 mg of total phenolics and from 49.1 to 109.2 mg of anthocyanins in 100 g of fresh cherry [Kim et al. 2005]. In an earlier study conducted in the same orchard, the fruits of four sour cherry cultivars were reported to have total anthocyanins of 45.0–67.1 mg in 100 g fresh fruit [Kim and Padilla-Zakour 2004]. In Hungarian studies, the content of anthocyanins in sour cherries varied from 20.25 to 99.45 mg·100 g f.w. [Veres et al. 2008] and from 11.3 to 93.5 mg·100 g f.w. [Papp et al. 2010] in dependence on genotype.

Anthocyanins are the major compounds of sour cherries phenolics and among them there are derivatives of cyanidin and peonidin. Their composition and concentration are influenced by the stage of maturity, cultivars, cultural practices, geographic origin, growing season and others [Kim and Padilla-Zakour 2004, Kim et al. 2005]. Among different plants or even cultivars in the same plant, the total anthocyanin content varies considerably, affected by genes, light, temperature, and agronomic factors [Horbowicz et al. 2008].

Anthocyanins and phenolics occurring in sour cherries are natural antioxidants having several beneficial effects on human's health [Chaovanalikit and Wrolstad 2004]. Several methods are used to determine the antioxidant activity of plant extracts and among them DPPD method [Cybul and Nowak 2008, Zych and Krzepiłko 2010, Gramza-Michałowska and Człapka-Matyasik 2011]. In the studies curried out by Chaovanalikit and Wrolstad [2004], antioxidant properties of 'Montmorency' fresh fruits determined as oxygen radical absorbance capacity (ORAC) and as ferric reducing antioxidant power (FRAP) were much higher than those of three sweet cherry cultivars. Until now there is no information about antioxidant activity and content of phenolics and anthocyanins in sour cherries grown in Poland.

Growth and yielding of sour cherry trees depends on soil nutrient availability [Mika 2004, Pacholak et al. 2011] and tree supply in mineral nutrients can be evaluated according to their content in the leaves [Sadowski et al. 1990, Mika 2004, Pacholak et al. 2011]. Optimal range of macroelements content in the leaves of sour cherries grown in Poland was determined by Sadowski et al. [1990] at the level of 2.30–2.80% of nitrogen, 0.15–0.30% of phosphorus, 1.20–1.80% of potassium, and 0.26–0.40% of magnesium.

Choice of a proper cultivar adopted well to the farm natural conditions as well as to the market demands is very important in sour cherry cultivation [Grzyb and Rozpara 2009]. Actually, 14 sour cherry cultivars are registered in Poland's National Cultivars Register (www.coboru.pl) and among them 'Kelleris 16', 'Łutówka', 'Nefris' and 'North Star' are of biggest importance [Mika 2004]. 'Łutówka' is the dominant cultivar making 80% of all sour cherry trees planted in Polish orchards [Jadczuk-Tobiasz and Bednarski 2007]. Several authors evaluated growth and yield of these cultivars in different parts of the country [Czynczyk et al. 1988, Selwa et al. 1994, Wociór 1997, Wociór and Kaca 2006, Jadczuk-Tobiasz and Bednarski 2007, Wociór et al. 2008, Podsiadło et al. 2009, Głowacka and Rozpara 2010, Pacholak et al. 2011].

Many pesticides are recommended in sour cherry cultivation, and among them dodine for cherry leaf spot (*Brumeriella jaapii* Rehm (Arx)) control and thiacloprid for black cherry aphid (*Myzus cerasi* F.) and European cherry fruit fly (*Rhagoletis cerasi* L.) control [Zalecenia Ochrony… 2016/2017]. In 2013 residues of 9 pesticides were detected in 5 to 33% of 20 sour cherry fruit samples collected in different regions of the country, however all were lower than permissible maximum residue level [Nowacka et al. 2015]. In the European Union the maximum residue levels for dodine and thiacloprid in fresh cherry fruits are 3.0 mg·kg^{-1} and 0.5 mg·kg^{-1} respectively [Part A of Annex to Reg. 396/2005].

In the last years a gradual process of climate warming is observed and this has some importance in sour cherry growing [Grzyb and Rozpara 2009].

The aim of this study was the comparison of some biometrical traits, yield, content of several biologically active compounds in the fruits and the antioxidant activity of three sour cherry cultivars grown in Lublin voivodship in the year 2015 characterized by a warm and wet spring as well as by a very hot and dry summer. An additional aim was the determination of dodine and thiacloprid residues in the fruits.

MATERIAL AND METHODS

The studies were carried out in an orchard located in Ożarów village near Nałęczów (51°17'N, 22°18'E) in 2015. Podzolic soil in the orchard developed from dusty medium loam contained 2.6% of organic matter and its pH was 6.7. Following content of assimilable forms of three macroelements was stated in the soil arable layer (in mg·100 g soil^{-1}) in the middle of August 2015: phosphorus (P) – 12.7, potassium (K) – 38.6 and magnesium (Mg) – 6.4.

First sour cherry trees of Kelleris 16, Łutówka and Nefris cultivars grafted on Mahaleb cherry were planted in 1995. The fruits of all three cultivars have dark skin and dark flesh. The trees were planted in the rows 4.0 m apart and within 2.0 m in the row on 4000 m² area. Then the orchard was enlarged gradually up to 2 ha area. The inter-rows were grassed down, with frequent grass mowing in conjunction with the maintenance of 1.5 m wide herbicide strips along the tree rows. The studies were conducted on twelve nineteen-years old trees of each cultivar chosen randomly in the oldest orchard part. Three trees were treated as one replicate in the experiment.

Since many years an integrated system of protection against diseases and insects was applied in the orchard [Zalecenia Ochrony… 2016/2017]. All agricultural practices realized in 2015 are presented in Table 1.

On June 27th the tree height, the diameter of trunk at 50 cm height and the diameter of tree-crown were measured.

The fruits were picked by hand at commercial maturity starting on July 20th and finishing on August 1st and total yield of fruits per tree was determined. Moreover, productivity index was calculated by dividing fruit yield by trunk cross-sectional area.

Samples of fruits picked on July 22nd were stored at 3–5°C and next day they were delivered to the Laboratory of Vegetables and Herb Row Material Quality at the Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin where the content of dry matter (oven dry method [Charłampowicz 1966]), soluble solids (refractometric method [Fernández 2014]), monosaccharides and total sugars (Schoorl-Luff's method [Charłampowicz 1966]), L-ascorbic acid (titrimetric method with 2,6-dichlorophenol indophenol [Nielsen 2017]), total anthocyanins (spectrophotometric method [Miłkowska and Strzelecka 1995]), individual anthocyanins (HPLC method [Najda 2004]), flavonoids (recalculated into quercetine – Christ-Miller's method, Farmakopea Polska IX 2011), phenolic acids [Farmakopea Polska VI 2002] and also activity of removal of DPPH (2,2-diphenyl-1-picrylhydrazyl) radicals (measured three times at the 20 $\mu g \cdot ml^{-1}$ Trolox concentration and expressed as percentage of DPPH inhibition [acc. to Chen and Ho 1997]) were determined.

Samples of fruits picked on July 22nd were delivered next day also to the Central Agroecological Laboratory of the University of Life Science in Lublin where the residues of dodine and thiacloprid in the fruits were determined using PN-EN 15662:2008 method approved by the Polish Centre for Accreditation. The sour cherry trees were sprayed with dodine on May 16th, May 28th and August 5th and the fruits were sampled 55 days after second treatment. Thiacloprid was applied on June 5th and the fruits were sampled 47 days after treatment. The waiting period for both pesticides was 14 days [Zalecenia Ochrony… 2016/2017].

On July 24th, diameter and fresh weight of 100 randomly picked ripe fruits and also leaf length and leaf blade diameter of 100 randomly chosen leaves collected from one replicate were measured.

On August 12th, samples of soil arable layer and of sour cherry leaves were delivered to the Regional Chemical – Agricultural Station in Lublin where the reaction and the content of organic matter in the soil and also the content of macroelements in the soil and in the leaves were determined.

Meteorological data were obtained from the nearest Agrometeorological Station of the Life Sciences University in Lublin placed 28 km away from the orchard.

The experiment was laid out in one factor randomized complete block design with four replications. The study results were analyzed statistically by analysis of variance, while the differences between means were estimated by Tukey's test at a significance level $P = 0.05$.

RESULTS AND DISCUSSION

The experiment was carried out in a commercial family orchard typical for this region. The sour cherry trees grew on a soil of proper reaction and abundant in mineral nutrients. The level of phosphorus, potassium, and magnesium availability in the soil arable layer was high [Mika 2004] and the content of nitrogen, phosphorus and potassium in the leaves was on optimum level, except for 'Łutówka' with high phosphorus content. Content of magnesium was high in the leaves of all studied cultivars (tab. 5) [Sadowski et al. 1990]. Content of nitrogen, phosphorus, potassium, and magnesium in sour cherry leaves stated in the experiment approximated that determined by Pacholak et al. [2011] in central-western part of Poland and content of calcium was considerable lower. Sour cherry trees were sprayed several times with different mixed foliar fertilizers (tab. 1) and probably this was not always necessary.

The weather conditions in 2015 were favourable for sour cherries cultivation. The winter was mild and the spring was warm and without spring frosts. Moreover, the rainfalls in the spring were higher than usually, especially in May. The summer was extremely hot and dry in comparison to may years' records in this region (tab. 2). Wet and warm spring followed by a hot and dry summer were conducive for fruit setting, growth and ripening and the yields

Table 1. Agricultural practices realized in the orchard in 2015

No.	Agricultural practice	Date
1	Tree spraying with Miedzian 50 WP (copper dioxide) 3.0 kg·ha^{-1}	April 11th
2	Grass mowing between tree rows	April 18th
3	Tree spraying with Rovral Aquaflo 500 SC (iprodione) 1.5 l·ha^{-1} and grass mowing	April 29th
4	Tree spraying with Syllit 65 WP 1.5 (dodine) kg·ha^{-1} + Cyperkill 250 EC (cypermethrin) 0.1 l·ha^{-1} + Kristalon Biały (mixed fertilizer with micronutrients) 3.0 kg·ha^{-1} + Wapnovit (calcium fertilizer with magnesium and micronutrients) 5.0 l·ha^{-1} and grass mowing	May 16th
5	Tree spraying with Syllit 65 WP 1.5 kg·ha^{-1} + Merpan 80 WG (captan) 2.0 kg·ha^{-1} + Fastac 100 EC (alpha-cypermethrin) 0.2 l·ha^{-1} + Kristalon Pomarańczowy (mixed fertilizer with EDTA or DTPA micronutrients) 3.0 kg·ha^{-1} + Wapnovit 5.0 l·ha^{-1} and grass mowing	May 28th
6	Spraying of herbicide strips with Roundup 360 SL (glyphosate) 3.0 l·ha^{-1} + Chwastox Extra 300 SL (MCPA) 0.3 l·ha^{-1}	June 4th
7	Tree spraying with Score 250 EC (difenoconazole) 0.2 l·ha^{-1} + Captan 80 WG (captan) 2.0 kg·ha^{-1} + Wapnovit 5.0 l·ha^{-1} + Solubor 3.0 (boron fertilizer) kg·ha^{-1} + Kristalon Pomarańczowy 3.0 kg·ha^{-1} + Calypso 480 SC (thiacloprid) 0.2 kg·ha^{-1}	June 5th
8	Grass mowing	June 13th
9	Tree spraying with Sadoplon 75 WP (thiuram) 4.5 kg·ha^{-1} + Score 250 EC 0.2 l·ha^{-1} + Kristalon Pomarańczowy 3.0 kg·ha^{-1} + Wapnovit 5.0 l·ha^{-1} + Siarczan magnezu (magnesium sulphate) 2.0 kg·ha^{-1}	June 20th
10	Tree spraying with Kaptan Plus 71.5 WP (70% captan + 1.5% triadimenol) 2 kg·ha^{-1} + Kristalon Pomarańczowy 3 kg·ha^{-1} + Wapnovit 5.0 l·ha^{-1} + Siarczan magnezu 3.0 kg·ha^{-1} and grass mowing	July 4th
11	Tree spraying with Syllit 65 WP 1.5 kg·ha^{-1}	August 4th
12	Grass mowing	August 14th
13	Tree pruning	August 18th
14	Tree spraying with Miedzian 50 WP 3.0 kg·ha^{-1} and grass mowing	November 5th

Table 2. Average monthly air temperatures and sums of rainfalls in 2015 compared to the long term averages (1951–2010)

Month	Temperature (°C)		Rainfalls (mm)	
	2015	1951–2010	2015	1951–2010
January	1.0	–3.7	46.8	23.4
February	0.9	–2.8	7.4	25.8
March	4.6	1.0	55.8	28.0
April	8.6	7.4	40.8	39.0
May	13.3	13.0	111.9	60.7
June	18.0	16.3	12.1	65.9
July	20.6	18.0	43.6	82.0
August	22.5	17.2	7.6	70.7
September	15.4	12.6	112.7	53.7
October	7.1	7.6	49.6	40.1
November	5.4	2.6	51.9	38.2
December	3.9	–1.6	30.6	31.4
Year's average	10.1	7.3	570.8	558.9

Table 3. Indices of tree growth and yield of compared sour cherry cultivars

Cultivar	TCSA* (cm^2)	Tree height (cm)	Tree-crown diameter (cm)	Fruit diameter (mm)	Fruit weight (g)	Fruit yield kg · $tree^{-1}$	Productivity index
Kelleris 16	190.2	366.7	232.8	19.62	5.31	29.3	0.15
Nefris	181.4	342.0	264.6	22.14	7.02	23.7	0.13
Łutówka	136.9	353.3	250.6	20.61	5.76	32.0	0.23
Average	169.5	354.0	249.3	20.79	6.03	28.3	0.17
$LSD_{0.05}$	26.42	n. s.	n. s.	1.692	1.163	4.26	0.041

* TCSA – trunk cross-sectional area

Table 4. Leaf lenght (mm), leaf blade width (mm) and content of macroelements in the leaves of compared sour cherry cultivars (% dry matter)

Cultivar	Leaf length	Blade width	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Kelleris 16	121	6.1	2.44	0.26	1.54	1.84	0.48
Nefris	130	5.3	2.68	0.25	1.25	1.49	0.46
Łutówka	125	5.5	2.32	0.35	1.37	1.41	0.50
Average	125	5.6	2.48	0.29	1.39	1.58	0.48
$LSD_{0.05}$	n.s.	n.s.	–	–	–	–	–

Table 5. Content of several components in the fruits and antioxidant activity of compared sour cherry cultivars

Cultivar	Dry matter (%)	Soluble solids (% Brix)	Total sugars (%)	Monosac-charides (%)	Vit. C (mg · 100 g $f.w.^{-1}$)	Anthocyanins (mg · 100 g $f.w.^{-1}$)	Phenolic acids (%)	Flavonoids (%)	DPPH (%)
Kelleris 16	11.5	11.6	15.1	11.6	21.1	88.0	0.131	0.009	85.4
Nefris	13.2	14.5	14.2	10.1	17.7	164.0	0.245	0.009	85.2
Łutówka	12.3	13.3	10.1	8.3	20.8	108.0	0.138	0.010	85.4
Average	12.3	13.1	13.1	10.0	19.9	120.0	0.171	0.000	85.3
$LSD_{0.05}$	0.64	0.38	0.25	0.61	0.37	4.51	0.0045	0.0003	n. s.

were fairly high and of good quality (tabs 3 and 5). During dry period, sour cherry trees could use spring rainfalls reserves gathered in the soil and high temperatures promoted production of biologically active compounds in the fruits [Horbowicz et al. 2008]. Wet and warm spring was favourable for the development of fungal diseases [Grzyb and Rozpara 2009] but they were controlled effectively using integrated protection program (tab. 1).

Indices presented in table 4 show that the sour cherry trees grew well. Trunk cross-sectional areas of ‘Kelleris 16’ and ‘Nefris’ did not differ significantly and were significantly bigger than that of ‘Łutówka’ (tab. 3) what confirms the results obtained by Grzyb et al. [1992/93]. Similar trunk diameter of 16-years old ‘Łutówka’ tree grafted on Mahaleb cherry stated Selwa et al. [1994] in the same natural conditions. Every year in August the trees were pruned by hand in a similar way so their height and crown diameter did not differ significantly (tab. 3).

Average leaf length of compared sour cherry cultivars was similar and ranged from 121 to 130 mm. The width of leaf blade was more differentiated and ranged from 53 to 61 mm. The leaf blade of ‘Kelleris 16’ was significantly wider than that of two other cultivars (tab. 4). No results related to this trait was found in the literature. Grzyb and Rozpara [2009] mentioned that ‘Kelleris 16’ leaves have wider blades. Wociór [1997] stated that fresh weight of one leaf developed by 9-years old ‘North Star’ tree ranged from 0.54 to 0.59 g in dependence on trunk height.

Fruits picked in the experiment had bigger weight and diameter than those harvested by many other authors [Czynczyk et al. 1988, Grzyb et al. 1992/93, Selwa et al. 1994, Wociór and Kaca 2006, Jadczuk-Tobiasz and Bednarski 2007, Wociór et al. 2008, Milošević and Milošević 2011] and similar to ‘Łutówka’ fruit weight determined by Głowacka and Rozpara [2010]. This also shows that the weather conditions in 2015 were conducive for sour cherry fruiting. ‘Nefris’ fruits were bigger than fruits of ‘Łutówka’ what agrees with the results obtained by Grzyb et al. [1992/93] and is not in line with measurements curried out by Czynczyk et al. [1988], though differences stated in the experiment were not significant. The smallest were the fruits of ‘Kelleris 16’ (tab. 3).

The fruit yield harvested from one tree ranged from 23.7 to 32.0 kg (tab. 3) and was similar to the yields harvested from 7–10 years old ‘Łutówka’ and ‘Nefris’ trees by Czynczyk et al. [1988]. However, it was less than the yields harvested from 9–11-years old ‘Łutówka’ trees by Wociór et al. [2008] and from 12-years old ‘Łutówka’ tree by Wociór and Kaca [2006]. The trees of Łutówka and Kelleris 16 cultivars produced yield significantly higher than ‘Nefris’ trees and this is not in line with the results obtained by Czynczyk et al. [1988]. The yields harvested from one sour cherry tree by several other authors were considerably smaller because the trees were much younger [Jadczuk-Tobiasz and Bednarski 2007, Podsiadło et al. 2009, Głowacka and Rozpara 2010].

Productivity index of compared 19-years old sour cherry trees ranged from 0.13 (‘Nefris’) to 0.23 (‘Łutówka’) $kg \cdot cm^{-2}$ (tab. 3) and was considerably lower than the indexes determined for 10-years old ‘Łutówka’ and ‘Nefris’ trees by Czynczyk et al. [1988] and Grzyb et al. [1992/93]. It was also lower than the index determined for 4–5-years old ‘Łutówka’ trees by Jadczuk-Tobjasz and Bednarski [2007].

Content of dry matter in the fruits ranged from 11.5 to 13.2% and was similar to that determined by Kunachowicz et al. [2017] though it was at low range level determined by Grzyb and Rozpara [2009] and lower than stated by Selwa et al. [1994]. The cultivars differed significantly in regard to this feature with ‘Nefris’ fruits having the highest and ’Kelleris 16’ fruits having the lowest dry matter content (tab. 5).

Content of total sugars (10.1–15.1%) and monosaccharides (8.3–11.6%) was approximate to the content of total and assimilable carbohydrates specified by Kunachowicz et al. [2017] and higher than determined by Podsiadło et al. [2009]. It was at the high range level determined by Grzyb and Rozpara [2009]. Content of monosaccharides was similar to the sum of glucose and fructose stated by Papp et al. [2010] in Hungarian sour cherries. The highest con-

Table 6. Individual anthocyanins determined in the fruits of compared sour cherry cultivars (mg · 100 g f.w.$^{-1}$)

Cultivar	Cyanidin 3-sophroside	Cyanidin 3-glucosyl-rutinoside	Cyanidin 3-glucoside	Cyanidin 3-xylosylrutinoside	Cyanidin 3-rutinoside	Peonidin 3-rutinoside	Sum
Kelleris 16	1.56	86.42	0.81	2.78	26.70	2.47	120.74
Nefris	3.45	61.20	1.09	1.40	29.13	1.30	97.57
Łutówka	1.98	76.30	0.67	2.57	24.34	2.23	108.09
Average	2.33	74.64	0.86	2.25	26.72	2.00	108.8
$LSD_{0.05}$	0.431	5.834	0.073	0.185	2.384	0.243	8.123

Table 7. Residues of dodine and thiacloprid in the fruits of compared sour cherry cultivars (mg · kg f. w.$^{-1}$)

Cultivar	Dodine	Thiacloprid
Kelleris 16	0.087 ±0.018	0.003 ±0.001
Nefris	0.037 ±0.008	< LOQ* = 0.002
Łutówka	0.038 ±0.009	< LOQ* = 0.002

* LOQ – lower limit of detection

tent of total sugars and monosaccharides was found in ‘Kelleris 16’ fruits and the lowest content in ‘Łutówka’ fruits with the differences being significant (tab. 5). The fruits grew and ripened during hot and dry weather and according to Podsiadło et al. [2009] content of sugars and vit. C in sour cherries increases at low soil humidity.

Content of vit. C in the fruits of all cultivars was considerably higher (tab. 5) than that stated by Podsiadło et al. [2009], Papp et al. [2010] and Kunachowicz et al. [2017] and approximate to the highest range level determined by Grzyb and Rozpara [2009]. The fruits of ‘Łutówka’ contained vit. C significantly more than ‘Kelleris 16’ and ‘Nefris’ fruits. ‘Nefris’ fruits did not differ from two other cultivars in regard to this trait. Varietal differences in vit. C content in sour cherry fruits stated also Veres et al. [2008] and Papp et al. [2010].

Content of total anthocyanins was differentiated significantly and ranged between 88.0 (‘Kelleris 16’) and 164 mg·100 g f.w.$^{-1}$ (‘Nefris’). It was higher than that in the studies conducted by Chaovanalikit and Wrolstad [2004], Kim and Padilla-Zakour [2004], Kim et al. [2005], Veres et al. [2008] and Papp et al. [2010]. Significant differences in anthocyanins content between two sour cherry cultivars reported Wang et al. [1997]. Among anthocyanins detected in sour cherry fruits, the most important components were cyanidin 3-glucosyl-rutinoside (61.20–86.42 mg·100 g f.w.$^{-1}$) and cyaniding 3-rutinoside (24.34–29.13 mg·100 g f.w.$^{-1}$). Content of other individual anthocyanins was considerably smaller and ranged from 0.67 to 3.45 mg·100 g f.w.$^{-1}$ (tab. 6). These results are generally in line with the findings stated by Kim et al. [2005] however in those studies peonidin 3-rutinoside was detected only in one of four studied cultivars. High content of anthocyanins in sour cherries indicates their importance in health maintaining because anthocyanins are probably the largest group of phenolic compounds in the human diet [Velioglu et al. 1998, Horbowicz et al. 2008, Veres et al. 2008].

In dependence on cultivar, sour cherries contained phenolic acids in the range from 0.131 to 0.245% (tab. 5) and this is in line with 146.1–312.4 mg of total phenolics determined in 100 g fruits of four sour cherry cultivars by Kim et al. [2005] and much less in comparison to 407 mg of total phenolics stated in 100 g of ‘Montmorency’ fruit edible portion by Chaovanalikit and Wrolstad [2004].

Fruits of compared sour cherry cultivars contained flavonoids from 0.0088 to 0.0095% (tab. 5) and this is similar to 8.74 mg content of four individual flavonols determined by Kim et al. [2005] in 100 g of 'Schattenmorelle' fruits and more than their content in the fruits of three other cultivars.

Antioxidant activity of fruits of compared sour cherry cultivars measured as percent of DPPH inhibition was similar and made 85.3% on an average (tab. 5). It was very high in comparison to that reported by Zych and Krzepiłko [2010] for selected antioxidants and infusions and high in comparison to reported by Gramza-Michałowska and Człapka-Matyjasik [2011] for several fruit chips extracts. Chaovanalikit and Wrolstad [2004] determined antioxidant activity of sour cherries also as high, however they used different analytical methods. High antioxidant activity of sour cherries stated in this experiment can be explained partially with high content of vit. C and anthocyanins [Velioglu et al. 1998, Chaovanalikit and Wrolstad 2004, Kim and Padilla-Zakour 2004, Kim et al. 2005, Veres et al. 2008, Papp et al. 2010]. Until now there is no information about content of anthocyanins and phenolic acids in the fruits of Polish sour cherry cultivars or about their antioxidant activity.

Residues of dodine determined 55 days after second tree spraying and 41 days after finishing of waiting period were found in the fruits of all three cultivars and ranged between 0.037 and 0.087 mg·kg f.w.$^{-1}$ (tab. 7). This was much less than the permissible maximum residue level (3.0 mg·kg f.w.$^{-1}$) determined in the Part A of Annex to EU Regulation No 396/2005. Residues of thiacloprid determined 47 days after treatment and 33 days after finishing of waiting period were found in 'Kelleris 16' fruits only at the quantity much lower (0.003 mg·kg f.w.$^{-1}$) than the permissible maximum residue level (0.5 mg·kg f.w.$^{-1}$). This confirms the data collected by Nowacka et al. [2015] showing that sour cherries produced in Poland are safe for the consumers.

CONCLUSIONS

19-years old well fertilized 'Kelleris 16', 'Nefris' and 'Łutówka' trees grown in central-eastern Poland and protected against pests using integrated plant protection system produced medium high and of good quality yield in the year characterized by a warm and wet spring and by a very hot and dry summer. Productivity index of trees of all cultivars was low what could be related with advanced tree age. The fruits of compared cultivars attained high weight and diameter and contained big amounts of sugars, vit. C, anthocyanins and flavonoids what was promoted by hot and dry weather. Among anthocyanins the most important were cyanidin 3-glucosyl-rutinoside and cyanidin 3-rutinoside. High content of biologically active compounds resulted in high antioxidant activity of fruits. Residues of dodine and thiaclporid determined in the fruits immediately after harvest were much lower than the permissible residue maximum level.

Łutówka was the most productive cultivar of medium leaf and fruit size and with fruits of highest vit. C and flavonoids content and lowest total sugars and monosaccharides content. The least productive cultivar was Nefris, though its fruits were the biggest and contained dry matter, soluble solids, anthocyanins and phenolic acids most of all and vit. C least of all. Kelleris 16 was the medium productive cultivar characterized by widest leaf blades and smallest fruits. Content of total sugars and monosaccharides in its fruits was the highest and content of anthocyanins and phenolic acids was the lowest.

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