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QUALITATIVE PROPERTIES OF THE FRUITS OF BLACKCURRANT *RIBES NIGRUM* L. GENOTYPES IN CONVENTIONAL AND ORGANIC CULTIVATION

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The aim of the investigation was to evaluate the effect of genotype and growing conditions on blackcurrant fruit weight and biochemical composition. The trial was carried out during the years 2011 and 2012 in South Estonia with two cultivation methods (conventional and organic) and eight genotypes of different genetic background, including two Scottish, 'Ben Alder' and 'Ben Lomond'; two Swedish 'Intercontinental' and 'Titania'; a Belarusian 'Pamyati Vavilova', and three recently selected genotypes from the Estonian blackcurrant breeding programme, 'Karri', 'Asker', and 'Mairi'. From each genotype and in both cultivation sites 500 g of fruit at full maturity was collected in three replications. Fruit weight, soluble solids (SS), sugars, organic acids, sugar/acid ratio, and ascorbic acid (AsA) concentrations were determined. Fruits from the organic cultivation site were smaller and contained more SS and sugars, they also had a higher sugar/acid ratio than conventionally grown berries. Organic acids and AsA concentrations were higher in berries from conventional cultivation systems compared to the organic ones. 'Karri' had the highest SS and sugar concentrations and sugar/acid ratio and the lowest concentration of acids on average over the years and cultivation methods. The highest AsA concentration was determined in 'Asker' and 'Ben Lomond'.

Key words: *fruit weight, °Brix, sugars, organic acids, ascorbic acid.*

INTRODUCTION

Blackcurrant (*Ribes nigrum* L.) is a valuable berry in human diet due to its high concentration of bioactive compounds and antioxidants which can be found mostly in berries, but in plant leaves and buds as well (Hummer and Barney, 2002; Raudsepp *et al*., 2010; Tabart *et al*., 2011; Vagiri *et al*., 2013). Blackcurrants possess a high antioxidant activity for which the phenolic compounds and ascorbic acid (AsA) make the major contribution (Lister *et al*., 2002). AsA concentrations in blackcurrants surpass many other fruit and berry cultures, and its stability has been described to be more consistent due to the presence of anthocyanins and other flavonoids (Hooper and Ayres, 1950; Miller and Rice-Evans, 1997). Nevertheless, the concentration of sugars, organic acids and their ratio also should not be underestimated, as these compounds play an essential role in the determination of taste properties and fruit quality (Bordonaba and Terry, 2008). The latter contribute to the use of blackcurrants as dessert fruits, and sweet berries are valuable ingredients for other tasty products with no need for additional sugars. Moreover, in addition to taste-related compounds, the fruit weight is important, being a genotype-dependent characteristic. Blackcurrant fruit quality and its nutritional value, including the concentration of AsA, sugars and organic acids depend on many factors such as genotype, latitude, cultivation conditions and agronomic practices (Anttonen and Karjalainen, 2006; Tabart *et al*., 2006; Pantelidis *et al*., 2007; Bordonaba and Terry, 2008; Brennan, 2008; Zheng *et al*., 2009a; 2012; Walker *et al*., 2010; Krüger *et al*., 2011; Vagiri *et al*., 2014), but the effect of genotype on the berry quality and on the concentration of bioactive compounds has been considered as the most important (Krüger *et al*., 2011; Vagiri *et al*., 2013; Woznicki *et al*., 2015b), with different genotypes responding differently according to growth area and conditions (Zheng *et al*., 2009b). Diverse results have been described in different cultivation areas. On the one hand, according to the investigations of Vagiri (2013; 2014) in Sweden, the accumulation of AsA increased in areas with warmer weather conditions when compared to the berries grown in cooler conditions. On the other hand, experiments conducted in Finland, Norway and Estonia obtained opposite results (Zheng *et al*., 2012, 2009b; Kaldmäe *et al*., 2013; Woznicki, 2015a).

Successively increasing areas of organically grown blackcurrants demand the selection of suitable cultivars from the aspect of the accumulation of bioactive compounds in berries and the effect of cultivation technology on fruit weight. Earlier studies in Poland and Estonia have found that organically cultivated berries contain more AsA compared to conventional ones (Kazimirmiercak *et al.*, 2008; Kahu *et al.*, 2009), but according to the results of Finnish researchers, the biochemical quality of organically grown blackcurrant fruits does not differ from those grown conventionally (Anttonen and Karjalainen, 2006). In the present study, fruit weight, and soluble solid, sugar, organic acid and AsA concentration of eight blackcurrant genotypes grown in organic and conventional cultivation systems in South-Estonia were determined in 2011 and 2012. The results enable to provide knowledge for blackcurrant growers in order to choose suitable cultivars with the desirable concentration of bioactive compounds and to obtain new information regarding to the effect of genotype on fruit biochemical composition.

MATERIAL AND METHODS

Experimental plot and conditions. The experiment was carried out in 2011–2012 at Polli Horticultural Research Centre of the Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences (58 °7'26''N, 25 °32'43''E). The cultivar evaluation plot in conventional system was established in autumn 2008 with two-year-old plants with spacing of 1.0 m in rows and 3.0 m between rows. The conventional experimental area was fertilised with 80 $t \cdot ha^{-1}$ of farmyard manure before planting. Each spring 300 $kg \cdot ha^{-1}$ of complex fertiliser Cropcare 6-14-23 (Kemira OY) was applied along the rows. The rows were mulched with milled peat and the space in between the rows was covered with grass and mowed four times during the summer period. There were no pesticides used in the plantation. The mineral composition of the soil in the plantation in 2011 was the following: P-383 $mg \cdot kg^{-1}$, K-291 $mg \cdot kg^{-1}$, Ca-1119 $mg \cdot kg^{-1}$, Mg-89 $mg \cdot kg^{-1}$, Cu-3.1 $mg \cdot kg^{-1}$, Mn-77 $mg \cdot kg^{-1}$, B-0.53 $mg \cdot kg^{-1}$, C_{org}-1.6%; the acidity of the soil was 5.3 pH_{KCL}.

The evaluation plot with organic conditions was established in autumn 2006 with one-year-old plants with a distance of 0.8 m in the row and 3.5 m between rows. In the previous year, a combination of oat (*Avena sativa* L.) and pea (*Pisum sativum* L.) was cultivated and ploughed into the soil as green manure. Each spring 130 g of organic fertiliser MONTERRA5-1-5 per bush and every autumn 5 kg of compost per bush were applied. The rows were mulched with milled peat and the space in between the rows was covered with grass and mowed four times during the summer period. The mineral composition of the soil in the plantation in 2011 was the following: P-189 $mg \cdot kg^{-1}$, K-139 $mg \cdot kg^{-1}$, Ca-1052 $mg \cdot kg^{-1}$, Mg-65 $mg \cdot kg^{-1}$, Cu-4.5 $mg \cdot kg^{-1}$, Mn-62 $mg \cdot kg^{-1}$, B-0.29 $mg \cdot kg^{-1}$, C_{org}-1.3%; the acidity of the soil was 5.3 pH_{KCL}. Both plantations were set on medium heavy loamy soil with rather good drought resistance; therefore, no irrigation system was used. There were no differences in plant protection between plots but the mineral composition of soil and the fertilisation schemes were somewhat different due to differences in cultivation methods.

Plant material and methods. The experiment involved a new genotype 'Karri' released in 2008 from the breeding programme of Polli Horticultural Research Centre, two genotypes 'Asker' and 'Mairi' registered in 2010, and five genotypes that are widely grown in Estonia and in Europe (Table 1). Three bushes per genotype, each bush as a replication, were included in the experiment. Fruit weight was calculated from the average of 100 berries from each bush. 500 g of berry samples per replication were collected in the middle of the harvesting season from the genotype evaluation test plots.

Table 1

ORIGIN OF THE TESTED BLACKCURRANT GENOTYPES

Genotype	Country	Pedigree
Ben Alder	Scotland	Ben More × Ben Lomond
Ben Lomond	Scotland	(Brödtorp × Janslunda) × (Consort × Magnus)
Pamyati Vavilova	Belorussia	Paulinka × Belorusskaya Sladkaya
Titania	Sweden	Altaiskaya dessertnaya × (Consort × Kajaanin Musta)
Intercontinental	Sweden	Ri74020-11 × Titania
Karri	Estonia	Mulgi must × Kantata 50
Asker	Estonia	Pamyati Vavilova × Öyebyn
Mairi	Estonia	Öyebyn × Kantata 50

For biochemical analysis, representative samples were prepared from field samples: 200 g of berries were homogenised using a kitchen blender and analysed on the same day for soluble solid (SS), sugar, organic acid and ascorbic acid (AsA) concentration. The SS concentration in the homogenised samples was recorded at 20 °C using an ABBE refractometer (Abbe WYA-1S, Optic Ivymen System), organic acids were determined by titration with 0.1 M NaOH. AsA was determined using the modified Tillman's method by titration with 2.6-dichlorophenol-indophenol under acidic conditions (Anonymous, 1984). The ferricyanide method was used for the sugar concentration analysis (Turkin and Shirokov, 1960). The concentration of AsA was expressed in mg per 100 g^{-1} of fresh weight (fw); sugars and acids in percent (%).

All results were tested by two-way analysis of variance (ANOVA). To evaluate the effect of genotypes, the least significant difference ($LSD_{0.05}$) for fruit weight and ($LSD_{0.01}$) for °Brix, sugar, organic acid and AsA concentration were calculated. Different letters on figures and tables mark significant differences at $p \leq 0.05$ or $p \leq 0.01$.

Weather conditions. The data of average, maximum and minimum temperatures and precipitation in May, June, and July of the testing years are presented in Table 2. The most favourable growing and ripening conditions were in 2012,

Table 2

MEAN, MAXIMUM, AND MINIMUM TEMPERATURES (°C) AND PRECIPITATION (MM) FROM APRIL TO JULY OF 2011 AND 2012 IN POLLI HORTICULTURAL RESEARCH CENTRE*

Year and month	Mean temp. (°C)	Max temp. (°C)	Min temp. (°C)	Precipitation (mm)
2011 May	10.8	27.4	-4.8	61.0
2011 June	19.0	29.0	7.0	0.6
2011 July	20.4	25.4	0.7	66.0
2012 May	11.3	23.5	-1.7	66.2
2012 June	13.0	23.7	1.6	50.8
2012 July	17.5	31.2	7.7	35.2

* Meteorological data collected by on site iMETOS weather station of Polli Horticultural Research Centre.

when daily temperature fluctuations were not great and precipitation was sufficient. The period with the poorest precipitation during growing and ripening was in 2011, as precipitation was very low in June.

RESULTS

Weight of fruit. Fruit weight of the tested genotypes was higher in 2012 for both conventional and organic cultivation, except for the genotype 'Mairi' which had the highest fruit weight in 2011 (Table 3). In both years, organic blackcurrants had smaller fruits in comparison to conventional ones, especially in the case of 'Karri' and 'Mairi'. On average for the two cultivation methods, the highest fruit weight was in 2011 in genotypes 'Intercontinental' and 'Mairi', and in 2012 only in 'intercontinental'. Fruit weight of cultivars 'Ben Alder' and 'Pamyati Vavilova' had no yearly differences; moreover, 'Ben Alder' had the lowest fruit weight in both experimental years. On average for the two years, the highest fruit weight was in conventionally grown 'Intercontinental', 'Karri' and 'vMairi' (1.6 g). The fruit weight remained on the same level on an average of two growing methods in genotypes 'Ben Alder', 'Pamyati Vavilova', and 'Asker'.

Table 3

THE WEIGHT AND CONCENTRATION OF SOLUBLE SOLIDS (°BRIX) OF FRUIT OF BLACKCURRANT GENOTYPES IN CONVENTIONAL AND ORGANIC CULTIVATION

CM*	Genotype	Weight of fruit (g) **			Soluble solids (°Brix) ***		
		2011	2012	Average	2011	2012	Average
Conventional	Ben Alder	0.9^{de}	0.8^{g}	0.9^{de}	14.7^{k}	16.3^{e}	15.5^{i}
	Ben Lomond	1.1^{c}	1.3^{bc}	1.2^{e}	17.9^{c}	15.4^{h}	16.7^{f}
	Pamyati Vavilova	1.0^{cd}	1.0^{f}	1.0^{d}	15.0^{j}	13.5^{k}	14.3^{k}
	Titania	1.1^{c}	1.3^{bc}	1.2^{c}	18.0^{c}	14.5^{j}	16.3^{g}
	Intercontinental	1.5^{b}	1.8^{a}	1.6^{a}	16.0^{gh}	14.8^{i}	15.4^{ij}
	Karri	1.4^{b}	1.8^{a}	1.6^{a}	15.5^{i}	16.3^{e}	15.9^{h}
	Asker	1.0^{cd}	1.3^{bc}	1.2^{c}	15.8^{h}	15.4^{h}	15.6^{i}
	Mairi	1.8^{a}	1.3^{bc}	1.6^{a}	16.9^{f}	15.8^{f}	16.4^{g}
Organic	Ben Alder	0.7^{e}	0.8^{g}	0.8^{e}	17.4^{de}	16.7^{d}	17.1^{e}
	Ben Lomond	0.8^{e}	1.2^{cd}	1.0^{d}	17.6^{d}	16.6^{d}	17.1^{e}
	Pamyati Vavilova	0.9^{de}	0.9^{fg}	0.9^{de}	16.1^{g}	15.6^{g}	15.9^{h}
	Titania	0.9^{de}	1.0^{ef}	1.0^{d}	19.0^{b}	19.3^{ab}	19.2^{b}
	Intercontinental	1.4^{b}	1.4^{b}	1.4^{b}	17.9^{c}	19.4^{a}	18.7^{c}
	Karri	1.1^{c}	1.2^{cd}	1.2^{c}	21.1^{a}	18.7^{c}	20.0^{a}
	Asker	1.1^{c}	1.2^{cd}	1.2^{c}	17.3^{e}	18.6^{c}	18.0^{d}
	Mairi	0.9^{de}	1.1^{de}	1.0^{d}	19.0^{b}	19.2^{b}	19.1^{b}
Effect of CM	Conventional	1.2^{a}	1.3^{a}		16.2^{b}	15.2^{b}	
	Organic	1.0^{b}	1.1^{b}		18.2^{a}	18.0^{a}	
Effect of genotype	Ben Alder	0.8^{d}	0.8^{e}		16.1^{g}	16.5^{d}	
	Ben Lomond	1.0^{c}	1.2^{c}		17.8^{d}	16.0^{e}	
	Pamyati Vavilova	1.0^{c}	1.0^{d}		15.6^{h}	14.6^{f}	
	Titania	1.0^{c}	1.2^{c}		18.5^{a}	16.9^{c}	
	Intercontinental	1.4^{a}	1.6^{a}		17.0^{e}	17.1^{b}	
	Karri	1.2^{b}	1.4^{b}		18.3^{b}	17.5^{b}	
	Asker	1.1^{bc}	1.3^{bc}		$16.^{6f}$	17.0^{bc}	
	Mairi	1.4^{a}	1.2^{c}		18^{c}	17.5^{a}	
		Conv.	Organic		Conv.	Organic	
Effect of year	2011	1.2^{b}	1.0^{b}		16.2^{a}	18.2^{a}	
	2012	1.3^{a}	1.1^{a}		15.2^{b}	18.0^{b}	

CM* Cultivation method; ** different letters in columns mark significant differences at $p \leq 0.05$; *** different letters in columns mark significant differences at $p \leq 0.01$.

Soluble solid (SS) concentration. The average SS concentration of blackcurrants was higher in 2011. Genotypes 'Ben Alder' and 'Karri' in conventional, and 'Titania', 'Intercontinental', 'Asker' and 'Mairi' in organic cultivation method had higher fruit SS concentration in 2012 (Table 3). In both years, organic blackcurrants contained higher SS concentration compared to conventional ones. On average for the two years, the highest concentration of SS was in the fruits of organically grown 'Karri' and the lowest in conventional 'Pamyati Vavilova', 20.0 and 14.3 °Brix, respectively. On average for the two cultivation methods, genotypes 'Titania' in 2011 and 'Karri' in 2012 had the highest SS concentration in fruits. The largest difference in SS concentration between the cultivation methods was in 'Karri' and the lowest in 'Ben Lomond'.

Total sugar concentration. Total sugar concentration in blackcurrants was higher in 2011, except 'Ben Lomond' in both cultivation methods and organically grown 'Asker' which were rich in sugars in 2012 (Table 4). On average for the two cultivation methods, 'Mairi' in organic cultivation in 2011 and 'Ben Alder' in conventional in 2012 had a higher total sugar concentration. On average of the two years, organically grown 'Karri' and 'Mairi' contained higher sugar concentration, while the lowest concentration was in the fruits of 'Titania' in the same conditions. Fruits grown in organic conditions had a higher concentration of total sugars when compared to conventional blackcurrants, except genotypes 'Ben Alder' and 'Titania which had increased total sugar concentration in case of conventional method. In comparison of the two cultivation methods, the largest difference in total sugar concentration was in genotype 'Intercontinental' and the smallest in 'Ben Lomond' and 'Mairi'.

Organic acid concentration. In 2011, fruits of different genotypes contained lower organic acid concentration when compared to year 2012, except conventional 'Ben Alder' which had a higher concentration in 2011 (Table 4). Conventional 'Pamyati Vavilova', 'Titania', 'Karri' and organic 'Ben Lomond', 'Karri', and 'Mairi' had no significant differences in organic acid concentration between the years. On average for the cultivation methods, the fruits of the genotype 'Intercontinental' had the highest acid concentration and 'Karri' had the lowest, while there was no effect on 'Titania'. In 2011, the average concentration of organic acids was equal within both cultivation methods, while in 2012, the conventionally grown blackcurrants had a higher concentration in comparison with the organic method.

The ratio of sugar and acid concentrations. In 2011, the highest sugar/acid ratio was in the fruits of organically grown 'Karri', and in 2012 conventional 'Ben Alder' (Table 5). On average for the two years, the ratio was higher in 2011 and the highest in the organically grown berries. On average for the two cultivation methods, the highest sugar/acid ratio was in fruits of 'Karri' in 2011. The lowest ratio was determined in conventionally grown 'Intercontinental' in 2012. A major difference between sugar/acid ratio of the two cultivation methods was found in the case of fruits of genotype 'Ben Alder', while there was no significant difference in 'Ben Lomond' and 'Titania'.

Ascorbic acid concentration (AsA). The AsA concentration in the fruits of different blackcurrant genotypes was higher in 2011 compared to 2012 (Table 5). The genotype 'Ben Lomond' in both cultivation systems and 'Karri' in organic cultivation had a higher AsA concentration in 2012. On an average of the two years, AsA concentration was higher in the berries of the conventionally grown 'Ben Lomond' (210 $mg{\cdot}100\ g^{-1}$ fw), followed by 'Asker' with 201 $mg{\cdot}100\ g^{-1}$ fw in the conventional and 197 $mg{\cdot}100\ g^{-1}$fw in the case of the organic method. There were significant yearly differences in the AsA concentration of the genotype 'Mairi' in the conventional and organic, and 'Asker' in the organic cultivation. On average for the two cultivation methods, the AsA concentration was the highest in 'Asker' (248 mg 100 g^{-1}·fw) in 2011 and in 'Ben Lomond' (196 $mg{\cdot}100\ g^{-1}$ fw) in 2012. A relatively low AsA concentration was determined in the fruits of 'Ben Alder' and 'Mairi' in 2012. Comparing the two cultivation methods, the largest difference in AsA concentration was found in 'Ben Lomond', and the least significant difference was in 'Titania' and 'Asker', while the cultivation method had no effect on AsA concentration in the genotype 'Pamyati Vavilova'.

DISCUSSION

Blackcurrant fruit weight is an important quality attribute depending significantly on the genotype, although affected by growing conditions as well (Brennan, 2008; Woznicki *et al.*, 2015). The results of the present experiment revealed that the genotype, the cultivation method and growing year had a significant effect on fruit weight of the selected blackcurrant genotypes (Table 3). The impact of the cultivation method was different depending on genotype, as neither the conventional nor the organic method affected the fruit weight of 'Ben Alder', 'Pamyati Vavilova', and 'Asker'. Similarly to our findings, a low fruit weight of the cultivar 'Ben Alder' has been observed in trials executed in Poland (Pluta *et al.*, 2005; Ochmian *et al.*, 2014). In earlier long-term studies, the genotype 'Asker' has shown low yearly variation in fruit weight (Kaldmäe *et al.*, 2013), but in the present experiment the differences between years are more notable, although having no effect on the fruit weight of cultivars 'Ben Alder' and 'Pamyati Vavilova'. The genotypes with large berries, such as 'Intercontinental', 'Karri' and 'Mairi' had a significantly lower fruit weight in the organic cultivation method as compared to the conventional, and in previous studies 'Intercontinental' has shown high yearly differences as well (Kaldmäe *et al.*, 2013). Trials in Norway have revealed the positive effect of precipitation and the negative impact of temperature on fruit weight (Woznicki *et al.*, 2015a), which correspond to our results. Blackcurrant berries were lighter in weight in 2011 when compared to 2012, probably due to low precipitation rate in June and July followed by the relatively high temperatures in July (Table 2), which affected fruit growth. The differences in soil mineral concentration of the plots, being lower in K and P in the conventional cultivation plot, might also have some influence on both fruit weight and chemical composition.

The results regarding blackcurrant SS and sugar concentration revealed the significant effect of genotype, yet the cultivation method and yearly weather conditions played important roles in their accumulation, as indicated by other authors as well (Zheng *et al.*, 2009a; Woznicki *et al.*, 2015b). The highest average fruit SS and sugar concentrations were detected in the organically grown 'Karri', while the sugar concentration of the organic fruits of 'Mairi' remained on the same level with 'Karri' (Table 4). A low SS concentration was determined in the conventionally grown berries of 'Pamyati Vavilova', which is in accordance with the results of earlier long-term trials with the same genotype (Kaldmäe *et al.*, 2013). Moreover, organic cultivation provided berries with higher SS and sugar concentration than the conventional cultivation method. According to Zheng *et al.* (2009b), different genotypes respond to the growing conditions diversely, and our results confirm the statement. The average SS and sugar concentration of the genotype ' 'Ben Lomond' showed low variation between the two cultivation methods, while the SS of 'Karri' was significantly increased by the organic cultivation method. The effect of weather conditions on blackcurrant fruit SS has been shown in Norway by Woznicki *et al.* (2015b), and our results are similar, as the fruit SS and sugar concentrations were higher in 2011 when the mean temperatures in June and July were higher than in 2012.

Organic acids are essential for the taste of blackcurrant fruits, as increased sugar and lower acid levels make the fruit taste sweeter. According to literature, fresh fruits for processing should contain 2.67 $g{\cdot}100\ ml^{-1}$ of organic acids (Ochmian *et al.*, 2014). The organic acid concentration of blackcurrant fruits depended significantly on the genotype, while the cultivation method had no effect on the average acidity. There were no differences in the concentration in 2011, but the average concentration of organic acids was

Table 4

CONCENTRATION OF THE TOTAL SUGARS AND ORGANIC ACIDS IN FRUITS OF BLACKCURRANT GENOTYPES IN CONVENTIONAL AND ORGANIC CULTIVATION

CM*	Genotype	Total sugars (%)			Acids (%)		
		2011	2012	Average	2011	2012	Average
Conventional	Ben Alder	9.5^{c**}	9.3^{a}	8.9^{c}	2.5^{g}	2.2^{j}	2.4^{g}
	Ben Lomond	6.4^{I}	8.3^{e}	7.9^{f}	2.6^{fg}	3.2^{fg}	2.9^{ef}
	Pamyati Vavilova	7.8^{j}	6.9^{i}	7.4^{h}	3.4^{b}	3.3^{ef}	3.4^{c}
	Titania	8.0^{i}	6.7^{j}	7.4^{h}	3.3^{b}	3.5^{cd}	3.4^{c}
	Intercontinental	8.4^{fg}	7.4^{h}	7.9^{f}	3.7^{a}	4.7^{a}	4.2^{a}
	Karri	8.5^{ef}	8.1^{f}	8.3^{d}	2.3^{h}	2.4^{i}	2.4^{g}
	Asker	8.2^{h}	6.3^{k}	7.3^{h}	2.8^{de}	3.6^{c}	3.2^{d}
	Mairi	10.1^{b}	8.8^{c}	9.5^{b}	2.9^{d}	3.8^{b}	3.4^{c}
Organic	Ben Alder	8.6^{de}	6.8^{ij}	7.7^{g}	2.8^{de}	3.1^{g}	3.0^{e}
	Ben Lomond	7.4^{k}	8.7^{c}	8.1^{e}	3.3^{b}	3.2^{fg}	3.3^{cd}
	Pamyati Vavilova	8.7^{d}	7.8^{g}	8.3^{d}	2.8^{de}	3.2^{fg}	3.0^{e}
	Titania	8.3^{gh}	5.6^{I}	7.0^{i}	3.1^{c}	3.4^{de}	3.3^{cd}
	Intercontinental	9.6^{c}	8.4^{de}	9.0^{c}	3.4^{b}	3.8^{b}	3.6^{b}
	Karri	10.2^{b}	9.1^{b}	9.7^{a}	2.3^{h}	2.4^{i}	2.4^{g}
	Asker	8.3^{gh}	8.5^{d}	8.4^{d}	2.7^{ef}	3.1^{g}	2.9^{ef}
	Mairi	10.9^{a}	8.4^{de}	9.7^{a}	2.7^{ef}	2.8^{h}	2.8^{f}
Effect of CM	Conventional	8.4^{b}	7.7^{b}		2.9^{a}	3.3^{a}	
	Organic	9.0^{a}	7.9^{a}		2.9^{a}	3.1^{b}	
Effect of genotype	Ben Alder	9.1^{c}	7.6^{d}		2.7^{d}	2.7^{e}	
	Ben Lomond	6.9^{f}	9.0^{a}		3.0^{c}	3.2^{d}	
	Pamyati Vavilova	8.3^{d}	7.4^{e}		3.1^{bc}	3.3^{cd}	
	Titania	8.2^{e}	6.2^{f}		3.2^{b}	3.5^{b}	
	Intercontinental	9.0^{c}	7.9^{c}		3.6^{a}	4.3^{a}	
	Karri	9.4^{b}	8.6^{b}		2.3^{e}	2.4^{f}	
	Asker	8.3^{d}	7.4^{e}		2.8^{d}	3.4^{bc}	
	Mairi	10.5^{a}	8.6^{b}		2.8^{d}	3.3^{cd}	
		Conv.	Organic		Conv.	Organic	
Effect of year	2011	8.4^{a}	9.0^{a}		2.9^{b}	2.9^{b}	
	2012	7.7^{b}	7.9^{b}		3.3^{a}	3.1^{a}	

CM*, cultivation method; ** different letters in columns mark significant differences at $p \leq 0.01$.

higher in organically grown berries of the genotypes under investigation in the next experimental year. The lowest acidity was recorded in the genotype 'Karri' and the highest in the fruits of 'Intercontinental'; the latter showed also the largest fluctuation in the concentration between the years and cultivation methods. Nevertheless, in general, the differences of the concentration of organic acids between the years are not remarkable, as reported in our earlier studies and in Norway as well (Kaldmäe *et al*., 2013; Woznicki *et al*., 2015b).

The sugar and acid ratio determines the perception of sweetness and is highly related to genotype. The taste of blackcurrants is especially important in the case of dessert berries. The highest sugar/acid ratio was recorded in the genotype ' 'Karri' and the lowest in 'Intercontinental'. The average sugar/acid ratio was increased by organic cultivation, although the genotypes 'Ben Lomond' and 'Titania' were not affected by the cultivation methods.

Blackcurrants are rich in antioxidants such as AsA, which has been proven to be genotype-dependent, but its accumulation can equally be influenced by the cultivation method and weather conditions (Zheng *et a*l., 2009a; 2012; Krüger *et al*., 2011; Vagiri *et al*., 2014; Woznicki *et al*., 2015b). In the present experiment, a significant effect of the genotype on the AsA concentration was revealed, showing the highest concentration in the fruits of 'Asker' and 'Ben Lomond'. In an earlier study, the genotype ' 'Asker' was also shown to have a high and stable AsA concentration (Kaldmäe *et al*., 2013). Organically grown fruits accumulated lower amounts of AsA compared to conventional ones; only in the genotype 'Titania' it was the opposite, although the fruits contained lower concentration of AsA, regardless of the cultivation method (Table 5). According to trials executed in Sweden, the cultivar 'Titania' has also shown low AsA concentration (Vagiri *et al*., 2014). The comparison of cultivation methods revealed that neither of the cultivation methods affected the AsA concentration in genotype 'Pamyati Vavilova' and had relatively little effect on 'Asker' and

Table 5

THE RATIO OF SUGARS AND ACIDS AND CONCENTRATION OF ASCORBIC ACID (ASA) IN FRUITS OF BLACKCURRANT GENOTYPES IN CONVENTIONAL AND ORGANIC CULTIVATION

CM*	Genotype	Sugars/acids			AsA (mg 100 g^{-1}fw)		
		2011	2012	Average	2011	2012	Average
Conventional	Ben Alder	3.8^{c}**	4.2^{a}	4.0^{a}	143^{g}	93^{j}	118^{j}
	Ben Lomond	2.4^{j}	2.6^{ef}	2.5^{e}	181^{c}	239^{a}	210^{a}
	Pamyati Vavilova	2.3^{jk}	2.1^{h}	2.2^{f}	153^{f}	117^{g}	135^{g}
	Titania	2.4^{j}	1.9^{i}	2.2^{f}	118^{j}	88^{k}	103^{I}
	Intercontinental	2.2^{j}	1.6^{j}	1.9^{g}	163^{d}	139^{e}	151^{e}
	Karri	3.6^{d}	3.4^{c}	3.5^{b}	115^{k}	93^{j}	104^{I}
	Asker	2.9^{gh}	1.7^{j}	2.3^{f}	224^{b}	178^{b}	201^{b}
	Mairi	3.5^{d}	2.3^{g}	2.9^{c}	158^{e}	84^{I}	121^{i}
Organic	Ben Alder	3.2^{e}	2.2^{gh}	2.7^{d}	92^{m}	83^{I}	88^{m}
	Ben Lomond	2.3^{jk}	2.7^{e}	2.5^{e}	109^{I}	152^{d}	131^{h}
	Pamyati Vavilova	3.0^{fg}	2.5^{f}	2.8^{dc}	164^{d}	104^{h}	134^{g}
	Titania	2.7^{i}	1.6^{j}	2.2^{f}	114^{k}	100^{i}	107^{k}
	Intercontinental	2.8^{hi}	2.2^{gh}	2.5^{e}	163^{d}	122^{f}	143^{f}
	Karri	4.4^{a}	3.7^{b}	4.1^{a}	141^{h}	171^{c}	156^{d}
	Asker	3.1^{ef}	2.7^{e}	2.9^{c}	271^{a}	123^{f}	197^{c}
	Mairi	4.0^{b}	2.9^{d}	3.5^{b}	130^{i}	77^{m}	104^{I}
Effect of CM	Conventional	2.9^{b}	2.5^{b}		157^{a}	129^{a}	
	Organic	3.2^{a}	2.6^{a}		148^{b}	117^{b}	
Effect of genotype	Ben Alder	3.5^{c}	3.2^{b}		118^{f}	88^{f}	
	Ben Lomond	2.4^{g}	2.7^{c}		145^{d}	196^{a}	
	Pamyati Vavilova	2.7^{e}	2.3^{d}		159^{c}	111^{d}	
	Titania	2.6^{ef}	1.8^{e}		116^{g}	94^{e}	
	Intercontinental	2.5^{fg}	1.9^{e}		163^{b}	131^{c}	
	Karri	4.0^{a}	3.6^{a}		128^{e}	132^{c}	
	Asker	3.0^{d}	2.2^{d}		248^{a}	151^{b}	
	Mairi	3.8^{b}	2.6^{c}		144^{d}	81^{g}	
		Conv.	Organic		Conv.	Organic	
Effect of year	2011	2.9^{a}	3.2^{a}		157^{a}	148^{a}	
	2012	2.5^{b}	2.6^{b}		129^{b}	117^{b}	

CM*, cultivation method; ** different letters in columns mark significant differences at $p \leq 0.01$.

‘Titania’. Our long-term experiments and studies carried out elsewhere have indicated the negative effect of high temperatures on AsA accumulation (Kaldmäe *et al*., 2013; Woznicki *et al*., 2015b). In the present experiment, the accumulation of AsA in 2011 was inhibited, probably due to increased temperatures during fruit ripening in June and July in comparison with the cooler growing conditions of 2012.

Cultivar selection for organic cultivation should take into account the way the fruit is consumed, as this determines the quality of the final product. The taste and size of the fruit used for processing is not of major importance in comparison to fresh consumption. Suitable genotypes for growing fruit for processing would be ones with a stable fruit weight and biochemical composition, especially in organic conditions. According to our results, the genotypes ‘Asker’, ‘Ben Lomond’, and ‘Pamyati Vavilova’ can be recommended for organic production and processing as the fruit weight did not decrease significantly and the first two genotypes had high AsA concentration as well. Furthermore, ‘Pamyati Vavilova’ has proven to be suitable for organic cultivation systems in previous trials (Kahu *et al*., 2009). The production of dessert blackcurrants demands large fruits and an acceptable taste. In organic cultivation conditions, the genotypes ‘Karri’ and ‘Mairi’ showed increased sugar concentration and sugar/acid ratio, but the only disadvantage could be the decreased fruit weight of organically grown berries.

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REFERENCES

Anonymous (1984). ISO 6557-2:1984. Fruits, vegetables and derived products — Determination of ascorbic acid concentration — Part 2: Routine methods Geneva: International Organization for Standardization.

Anttonen, M. J., Karjalainen, R. O. (2006). High-performance liquid chromatography analysis of black currant (*Ribes nigrum* L.) fruit phenolics grown either conventionally or organically. *J. Agric. Food Chem*., **54**, 7530?7538.

Bordonaba, G. J., Terry, L. A. (2008). Biochemical profiling and chemometric analysis of seventeen UK-grown blackcurrant cultivars. *J. Agric. Food Chem*., **56** (16), 7422–7430.

Brennan, R. M. (2008). Currants and gooseberries. In: Hancock, J. F. (Ed.). *Temperate Fruit Crop Breeding*. Springer, Berlin, pp. 177–196.

Hooper, F. C., Ayres, A. D. (1950). The enzymatic degradation of ascorbic acid. Part 1. The inhibition of the enzymatic oxidation of ascorbic acid by substances occurring in black currants. *J. Agric. Food Chem*., **1**, 5–8.

Hummer, K. E., Barney, D. L. (2002). Currants. *Hort. Technol.*, **12** (3), 377–387.

Kahu, K., Jänes, H., Luik, A., Klaas, L. (2009). Yield and fruits quality of organically cultivated black currant cultivars. *Acta Agri. Scan. Section B-Soil and Plant Sci*., **59**, 63–69.

Kaldmäe, H., Libek, A-V., Arus, L., Kikas, A. (2013). Genotype and microclimate conditions influence ripening pattern and quality of blackcurrant (*Ribes nigrum* L.) fruit. *Zemdirbyste / Agriculture,* **100** (2), 167–174.

Kazimierczak, R., Hallmann, E., Rusaczonek, A., Rembiałkowska, E. (2008). Antioxidant concentration in black currants from organic and conventional cultivation. *J. Polish Agri. Uni*., **11** (2), 28.

Kruger, E., Dietrich, H., Hey, M., Patz, C. D. (2011). Effects of cultivar, yield, berry weight, temperature and ripening stage on bioactive compounds of black currants. *J. Appl. Bot. Food Qual*., **84**, 40–46.

Lister, C. E., Wilson P. E., Sutton, K. H., Morris, S. C. (2002). Understanding the health benefits of blackcurrants. *Acta Hortic*., **585**, 443–449.

Miller, N. J., Rice-Evans, C. A. (1997). The relative contributions of ascorbic acid and phenolic antioxidants to the total antioxidant activity of orange and apple fruit juices and blackcurrant drink. *Food Chem.*, **60**, 331–337.

Ochmian, I. D., Dobrowolska, A., Chełpiński, P. (2014). Physical parameters and chemical composition of fourteen blackcurrant cultivars (*Ribes nigrum* L.). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **42** (1), 160–167.

Pantelidis, G. E., Vasilakakis, M., Manganaris, G. A., Diamantidis, Gr. (2007). Antioxidant capacity, phenol, anthocyanin and ascorbic acid concentrations in raspberries, blackberries, red currants, gooseberries and Cornelian cherries. *Food Chem.*, **102**, 777–783.

Pluta, S., Zurawicz E., Broniarck-Niemiec, A. (2005). Comparison of the production value of new Polish blackcurrant clones and selected foreign cultivars. *Zesz. Nauk ISK*, **13**, 63–68.

Raudsepp, P., Kaldmäe, H., Kikas, A., Libek, A.-V., Püssa, T. (2010). Nutritional quality of berries and bioactive compounds in the leaves of black currant (*Ribes nigrum* L.) cultivars evaluated in Estonia. *J. Berry Res.*, **1**, 53–59.

Tabart, J., Kevers, C., Pincemail, J., Defraigne, J-O., Dommes, J. (2006). Antioxidant capacity of black currant varies with organ, season and cultivar. *J. Agric. Food Chem*., **54** (17), 6271–6276.

Tabart, J., Kevers, C., Evers, D., Dommes, J. (2011). Ascorbic acid, phenolic acid, flavonoid, and carotenoid profiles of selected extracts from *Ribes nigrum. J. Agric. Food Chem.,* **59** (9), 4763–4770.

Turkin, V. A., Shirokov, E. P. (1960). *Processing and Preservation Technologies for Fruit and Vegetables* [Туркин, В. А., Широков, Е. П. *Технология хранения и переработки плодов и овощей*]. Gossudarstvennoje izdatelstvo selskohozijaistvennoi literature, Moscow, pp. 149–156 (in Russian).

Vagiri, M., Ekholm, A., Öberg, E., Johansson, E., Andersson, S., Rumpunen, K. (2013). Phenols and ascorbic acid in black currants (*Ribes nigrum* L.): Variation due to genotype, locations and year. *J. Agric. Food Chem.,* **61**, 9298–9306.

Vagiri, M. R. (2014). Phenolic compounds and ascorbic acid in black currant (*Ribes nigrum* L.): Variation due to Genotype, Ontogenetic Stage, Harvest. Doctoral Thesis Swedish University of Agricultural Sciences, Alnarp, Sweden. 68 pp.

Walker, P. G., Viola, R., Woodhead, M., Jorgensen, L., Gordon, S. L., Brennan, R. M., Hancock, R. D. (2010). Ascorbic acid concentration of black currant fruit is influenced by both genetic and environmental factors. *Funct. Plant Sci. Biotechnol*., **4**, 40–52.

Woznicki, T. L., Heide, O. M., Sonsteby, A., Wold, A. B., Remberg, S. F. (2015a). Effects of controlled post-flowering temperature and daylength on chemical composition of four black currant (*Ribes nigrum* L.) cultivars of contrasting origin. *Sci. Hortic*., **197**, 627–636.

Woznicki, T. L., Heide, O. M., Sonsteby, A., Wold, A. B., Remberg, S. F. (2015b). Yield and fruit quality of black currant (*Ribes nigrum* L.) are favoured by precipitation and cool summer conditions. *Acta Agric. Scand. Sect. B Soil Plant Sci.,* **65**, 702–712.

Zheng, J., Kallio, H. and Yang, B. (2009a). Effect of latitude and weather conditions of sugars, fruit acids and ascorbic acid in currant *(Ribes* sp.) cultivars. *J. Sci. Food Agric*., **89** (12), 2011–2023.

Zheng, J., Yang, B., Tuomasjukka, S., Ou, S., Kallio, H. (2009b). Effect of latitude and weather conditions of sugars, fruit acids and ascorbic acid in black currant (*Ribes nigrum*). *J. Agric. Food Chem*., **57** (7), 2977–2987.

Zheng, J., Yang, B., Ruusunen, V., Laaksonen, O., Tahvonen, R., Hellsten, J., Kallio, H. (2012). Compositional differences of phenolic compounds between black currant (*Ribes nigrum* L.) cultivars and their response to latitude and weather conditions. *J. Agric. Food Chem*., **60**, 6581–6593.

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OGU KVALITĀTE KONVENCIONĀLAJĀ UN BIOLOĢISKAJĀ AUDZĒŠANĀ UPEŅU *RIBES NIGRUM* L. GENOTIPIEM

Pētījuma mērķis bija novērtēt genotipa un augšanas apstākļu ietekmi uz upeņu ogu masu un bioķīmisko sastāvu. Izmēģinājums tika veikts 2011. un 2012. gadā Dienvidigaunijā, izmantojot divas audzēšanas metodes (konvencionālo un bioloģisko) un atšķirīgas ģenētiskās izcelsmes genotipus, tai skaitā divus Skotijas izcelsmes ‘Ben Alder’ un ‘Ben Lomond’, divus Zviedrijas izcelsmes ‘Inter Continental’ un ‘Titania’, vienu Baltkrievijas izcelsmes ‘Pamyati Vavilova’, un trīs genotipus no Igaunijas selekcijas programmas: ‘Karri’, ‘Asker’ un ‘Mairi’. Analīzēm abās audzēšanas vietās tika ievākti 500 g ogu pilngatavībā no katra genotipa trīs atkārtojumos. Tika noteikta ogu masa, šķīstošā sausna (SS), cukuri, organiskās skābes, cukura/skābes attiecība un askorbīnskābes (AsA) saturs. Bioloģiski audzētās ogas bija mazākas, saturēja vairāk šķīstošās sausnas un cukuru, tām bija arī augstāka cukura/skābes attiecība nekā konvencionāli audzētajām ogām. Organisko skābju un askorbīnskābes saturs konvencionāli audzētās ogās bija augstāks salīdzinot ar bioloģiski audzētajām. Šķirnei ‘Karri’ bija augstākais šķīstošās sausnes saturs un cukura/skābes attiecība un zemākais skābju saturs vidēji abos audzēšanas gados un audzēšanas metodēs. Augstākais askorbīnskābes saturs tika konstatēts šķirnēm ‘Asker’ un ‘Ben Lomond’.