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Newly introduced strawberry genotypes for Nordic Baltic conditions

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Abstract

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Eight recently introduced strawberry genotypes 'Chambly', 'Clery', 'Darselect', 'Delia', 'Harmonie', 'Matis', 'Sallybright', 'Salsa' and 'Senga Sengana' (standard cultivar) were evaluated at the Polli Horticultural Research Centre of the Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences. Phenology, winter hardiness, strawberry blossom weevil (*Anthonomus rubi*) injury, yield, fruit weight, soluble solids, sugar, acid and ascorbic acid content of the fruit were determined. Genotypes more suited to the Estonian climate conditions are the winter hardy, late-yielding cultivars 'Salsa' and 'Harmonie'. 'Salsa' has a good, high quality yield with large attractive fruit. The fruit of 'Harmonie' contains much ascorbic acid, but the sugar-acid ratio is less balanced. Early genotypes 'Chambly', 'Clery', 'Darselect', 'Delia', 'Sallybright' and the late genotype 'Matis' have a lower yield than the standard cultivar 'Senga Sengana'.

Keywords: cultivar; winter hardiness; yield, fruit weight; biochemical composition; GDD

Strawberry is a widespread cultivated berry in Europe (Höfer 2012; Kårlind et al. 2015). Even in harsh Northern European climatic conditions strawberries can be grown successfully. According to Statistics Estonia, there were 675 hectares of strawberries grown in Estonia in 2015. In harsh weather conditions, it is very important to choose the right genotype. Nowadays, the cultivars 'Polka' and 'Sonata' are most widely cultivated in Estonia, and, to a lesser extent, the late ripening cultivar 'Florence', which often suffers from winter damage in these weather conditions. There is no breeding program for strawberries in Estonia, so the only option for improving the variety available is to use genotypes developed elsewhere. The important aspects in selecting suitable genotypes are winter hardiness, yield and resistance to pests and diseases over the course of several years. However, the requirements for genotypes are changing over time. Aside from the importance of a good yield, qualitative properties like fruit size and nutrient content are gaining importance.

Several researches have shown that strawberries contain many compounds beneficial to the human body, such as ascorbic acid, polyphenols including anthocyanins, phenolic acids, flavonols etc. (Hakala et al. 2003; Anttonen et al. 2006; Aaby et al. 2007; Josuttis et al. 2012). Strawberries are used in desserts and therefore their taste is very important. The ratio between sugar and acids in strawberries and in other berries can act as an important indicator of fruit taste (Bordonaba, Terry 2008, 2010; Crespo et al. 2010). In organic strawberry growing, there is a need for genotypes with a high

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tolerance to pests and diseases (Weissinger et al. 2014). All these properties are largely determined by genotype, but they are also influenced by harvest and pre-harvest weather conditions (temperature, precipitation etc.), the habitat, production system and other factors. However, different genotypes can perform differently (Krüger 2012). Research has shown that strawberries that were grown in different environmental conditions have a different biochemical composition depending on the genotypes (Kårlind et al. 2015), although, Crespo et al. (2010) corroborates the dominant role of strawberry genotype over environmental factors.

The aim of the present study is to find suitable strawberry genotypes for Estonian conditions that have a high yield, attractive fruit and an acceptable biochemical composition. Besides the genotype, the yield and its quality depend on multiple factors and therefore it is important to test the suitability of the genotype in local conditions. Positive test results in local conditions give confidence to the growers and a valuable feedback to the breeder about the performance of the genotype in different regions.

MATERIAL AND METHODS

The research was carried out in 2011–2013 at the Polli Horticultural Research Centre. The cultivar evaluation plot in South-Estonia, Polli (58°7'6''N, 25°32'43''E) was established in the spring of 2010 with eight new cultivars: 'Chambly', 'Clery', 'Darselect', 'Delia', 'Darselect', 'Harmonie', 'Matis', 'Sallybright', 'Salsa' and 'Senga Sengana' as the standard cultivar.

Three replications, 10 plants in each, were planted at distances of 0.3 × 1.2 m using black plastic mulch. The soil was soddy podzolic clay loam. No irrigation and plant protection treatments were applied. The NPK-mineral fertilizer Cropcare 8-11-21 (Yara international, Finland) was added before planting (600 kg/ha). One teaspoon of the fertilizer Cropcare 8-11-21 per plant was applied under the black plastic mulch each spring, starting from the second year. The vegetation between the plant rows was controlled mechanically by mowing. Weeds around the plants were removed manually and runners removed once per vegetation period in August.

For each cultivar, the onset of flowering and the beginning of harvest were recorded and based on this, the growing degree days (GDD) to anthesis and from anthesis and harvest start were calculated as follows:

$$GDD = (T_{max} + T_{min}/2) - T_{base}$$

where: T_{max}, T_{min} – daily max. and min. temperatures; T_{base} – base temperature (McMaster, Wilhelm 1997)

The base temperature of 3°C was used (Døving, Måge 2001). Winter damage was evaluated on the scale of 1–9 points each spring during the intensive growth of the leaves as follows: (1) healthy plants, to (9) all plants destroyed. The strawberry blossom weevil damage was determined as percent of flowers with blossom weevil injury from the total number of flowers counted in 5 plants per replication. Fruits were picked every second day or, at the end of the harvest period, every third day. The total yield and the fraction of damaged fruit (malformed and damaged by fungi, etc.) were weighted and the percentage of damaged fruit was calculated. The weight of 20 fruits was determined in each lot and the mean fruit weight was calculated.

The total number of flowers and flowers with blossom weevil injury in the five strawberry plants was counted on each plot and the percentage of damaged flowers was calculated.

For the biochemical analysis, the representative samples were prepared from the field samples: 200 g of berries were homogenized using a kitchen blender and analysed on the same day for soluble solids, sugars, organic acids and ascorbic acid content. The soluble solids content in the homogenized samples was recorded at 20°C using an ABBE refractometer (Abbe WYA-1S, Optic Ivymen System, Spain), organic acids were determined by titration with 0.1 M NaOH. Ascorbic acid was determined using the modified Tillman's method by titration with 2.6-dichloroindophenol under acid conditions (ISO 6557-2:1984 – Fruits, vegetables and derived products – Determination of ascorbic acid content – Part 2: Routine methods). The ferricyanide method was used for the sugar content analysis (Turkin, Shirokov 1960). The content of ascorbic acid was expressed in mg per 100 g of fresh berries; sugars and acids in percent.

All results were tested by one- and two-way analysis of variance (ANOVA). To evaluate the effect of genotypes, the least significant difference ($LSD_{0.05}$) was calculated. Different letters in figures and tables mark significant differences at $P \leq 0.05$.

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RESULTS AND DISCUSSION

Phenology, winter and blossom weevil damage

In northern climates, winter damage often occurs in strawberry plantations(Sønsteby, Karhu 2005). In Estonia, strawberry plants are injured when snow cover is insufficient (Kikas, Libek 2004). In the testing years, the snow cover was sufficient for good overwintering of most strawberry genotypes. In 2011, minimal injury occurred to genotypes 'Delia' and 'Matis' and, in 2012, to genotypes 'Clery', 'Chambly' and 'Matis'. In 2013, there was no winter damage.

Strawberry blossom weevil damage was evaluated only in 2011, in other years, notable injury did not occur. In 2011, 'Clery' suffered the biggest damage (23.7%); 'Darselect' (16.2%), 'Delia' (16.2%) and 'Salsa' (13.2%) were also affected; in 'Harmonie' (5.2%) the injury was not so severe. The rest of the genotypes were not affected. The reason for 'Clery' suffering the biggest damage was due to the small number of blossoms, which was also the case for 'Darselect' and 'Delia'. Previous research done in Estonia and in Austria showed that the blossoms of late genotypes are mostly less damaged than early genotypes, but the genetic background of genotypes is important as well (Kikas et al. 2009; Weissinger et al. 2009, 2012). The research results confirm the importance of genotype in the context of blossom weevil injury. In 2011, the flowering began almost simultaneously, so the flowering time did not affect the rate of the injury. On the contrary, research in Poland confirms that the weather conditions during the year have much stronger influence on the injury of the blossom weevil than either genotype or flowering time (Łabanowska 2004).

The onset of the flowering of the strawberry genotypes was the latest, but relatively simultaneous, in 2011. May was relatively cool, the end of May and the beginning of June were unusually warm; GDD values for anthesis were 311–370 GDD (Table 1). The greatest difference in the anthesis of the genotypes was in 2012: the early genotypes, 'Chambly', 'Clery', 'Darselect' and 'Delia' needed only 256–285 GDD for anthesis whereas the late genotype 'Harmonie' needed 348 GDD. In 2013, the GDD for anthesis in the strawberry genotypes was 245–297 GDD. In 2011, the ripening of the fruit was very fast, it took only 21–24 days from anthesis to the beginning of harvest; except for the genotypes 'Harmonie' and 'Matis' were it took 26 and 27 days, respectively. As an average over the years, 21–36 days were needed from anthesis to harvest. The variation over the years was large, but no significant difference between the genotypes was revealed. The average GDD values from anthesis to the start of the harvest were quite similar for the genotypes: 'Harmonie' had the highest GDD value (352 GDD), followed by 'Salsa' and 'Clery' with GDD values of 344 and 332 GDD respectively; the latter had a similar GDD value (320 GDD) in the trial in Switzerland (Krüger et al. 2012). The period from anthesis to the start of the harvest was shortest for genotype 'Sallybright' with a GDD value of 288 GDD.

Yield, fruit weight and damaged fruit

In 2011, the yield of the strawberry genotypes was very low, in most genotypes it was at the same level

Table 1. Growing degree days (GDD, base temperature 3°C) to anthesis and from anthesis to harvest start

Genotype	GDD to anthesis				GDD from anthesis to harvest start			
	2011	2012	2013	Average	2011	2012	2013	Average
Senga Sengana	311	302	285	299 ± 13.2^{bc}	326	292	347	322 ± 27.8^{abc}
Chambly	318	270	227	272 ± 45.5^{d}	318	293	364	325 ± 36.0^{abc}
Clery	311	256	245	271 ± 35.4^{d}	303	307	388	333 ± 48.0^{ab}
Darselect	328	270	276	291 ± 31.9^{cd}	308	293	357	319 ± 33.5^{abc}
Delia	328	285	261	291 ± 33.9^{cd}	308	256	371	312 ± 57.6^{bc}
Harmonie	370	348	297	338 ± 37.4^{a}	356	326	375	352 ± 24.7^{a}
Matis	357	329	285	324 ± 36.3^{ab}	369	265	347	327 ± 54.8^{ab}
Sallybright	338	302	285	308 ± 27.1^{bc}	298	261	306	288 ± 24.0^{c}
Salsa	328	302	297	309 ± 16.6^{bc}	333	325	375	344 ± 26.8^{ab}

different letters in columns mark significant differences at $P \leq 0.05$

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Table 2. Yield, percentage fruits and weight of strawberry genotypes

Genotype	Yield (g/plant)			Damaged fruit (%)	Fruit weight (g)		
	2011	2012	2013	Average of years	2011	2012	2013
Senga Sengana	128[ab]	631[b]	207[bc]	4.8[ab]	6.6[c]	9.5[d]	7.3[e]
Clery	89[bc]	166[d]	119[c]	1.7[c]	13.4[a]	14.4[bc]	9.0[cde]
Chambly	74[c]	392[c]	219[bc]	2.2[c]	9.1[bc]	14.8[bc]	8.9[cde]
Darselect	100[bc]	369[c]	213[bc]	3.2[bc]	13.4[a]	21.3[a]	13.0[a]
Delia	95[bc]	375[c]	176[bc]	2.4[bc]	10.1[ab]	13.7[bc]	10.0[bcd]
Harmony	169[ab]	662[b]	365[a]	4.7[ab]	13.4[a]	13.1[c]	8.6[de]
Matis	78[c]	278[cd]	165[bc]	1.8[c]	10.5[ab]	15.7[b]	11.7[ab]
Sallybright	80[c]	253[cd]	162[bc]	6.4[a]	10.2[ab]	15.8[b]	10.8[abcd]
Salsa	164[ab]	885[a]	278[ab]	3.4[bc]	12.6[a]	20.5[a]	11.1[abc]

different letters in columns mark significant differences at $P \leq 0.05$

as the yield of the standard cultivar 'Senga Sengana', only 'Chambly', 'Sallybright' and 'Matis' produced less fruit than the standard cultivar (Table 2). The negative impact on the yield was due to heavy blossom weevil injury, high temperature and drought. The weather conditions that hindered the development of the fruit were advantageous to blossom weevil. The yield in the first year of the harvest is relatively small, because the plant had less crown branches than in the second year (Krüger et al. 2012) and the number of blossoms per plant was also relatively low (data not presented). In 2012, the yield of the strawberry genotypes was the highest of the research years. 'Salsa' had the highest yield; the yield of 'Harmonie' was similar to the standard cultivar. The rest of the genotypes yielded less than the standard cv. 'Senga Sengana'. In 2013, the strawberry genotypes yield was also small, it exceeded the yield that was in 2011 but did not exceed the yield of 2012. Over the research years, 'Salsa' and 'Harmonie' had the highest average yield; the yield of other genotypes was lower than that of the standard cultivar (Fig. 1a). Other researchers have also confirmed the high yielding of 'Salsa' (Spornberger et al. 2008; Masny, Żurawicz 2009). In our trial, 'Clery' had the lowest yield; the yields of 'Sallybright' and 'Matis' were in a similar range. 'Clery' and 'Darselect' were reported to have low yield in Austria as well (Spornberger et al. 2008). A research in Germany showed that 'Darselect' also had a low yield, but 'Clery' had a medium yield (Pliffer 2008). In Switzerland, the genotypes 'Clery' and 'Matis' gave high yields but they gave low yields in our trial (Crespo et al. 2010).

The percentage of damaged fruit was relatively low through the research years, staying between 3.1–3.9% of the total yield. 'Sallybright' had the highest percentage of damaged fruit, which was similar to the standard cultivar 'Senga Sengana'. The average weight of fruit over the genotypes was smaller in 2011 compared to 2012 (Table 2). The development of fruit size was hindered because of very high temperature and drought during fruit formation (Table 3). The largest fruits were in 2012, when there was enough precipitation during the fruit development and the temperature was not very high. In 2013, the fruits were the smallest. (Table 2). On average, over the years the fruit weight of all genotypes was higher than that of the standard cultivar. 'Darselect' and 'Salsa' had the largest fruit, the weight of fruit 15.9 and 14.7 g, respectively (Fig. 1b). 'Salsa' had large fruit also in the Polish trial (Masny, Żurawicz 2009), in Austria the fruit weight of 'Salsa' was lower than in our trial and the fruits of 'Darselect' and 'Clery' were also small (Spornberger et al. 2008).

The soluble solids (Brix°), sugar and acid content of fruit are important characteristics of fruit quality. The ratio between sugar and acid in strawberries and in other berries can act as an important indicator of fruit taste. In 2011, Brix° and sugar content was considerably higher than in 2012. Over the research years, particularly large variations in sugar content were observed in the genotype 'Clery'. According to Krüger et al. (2012), fruits that are grown at northern latitudes contain more soluble solids and titratable acids than fruits grown at

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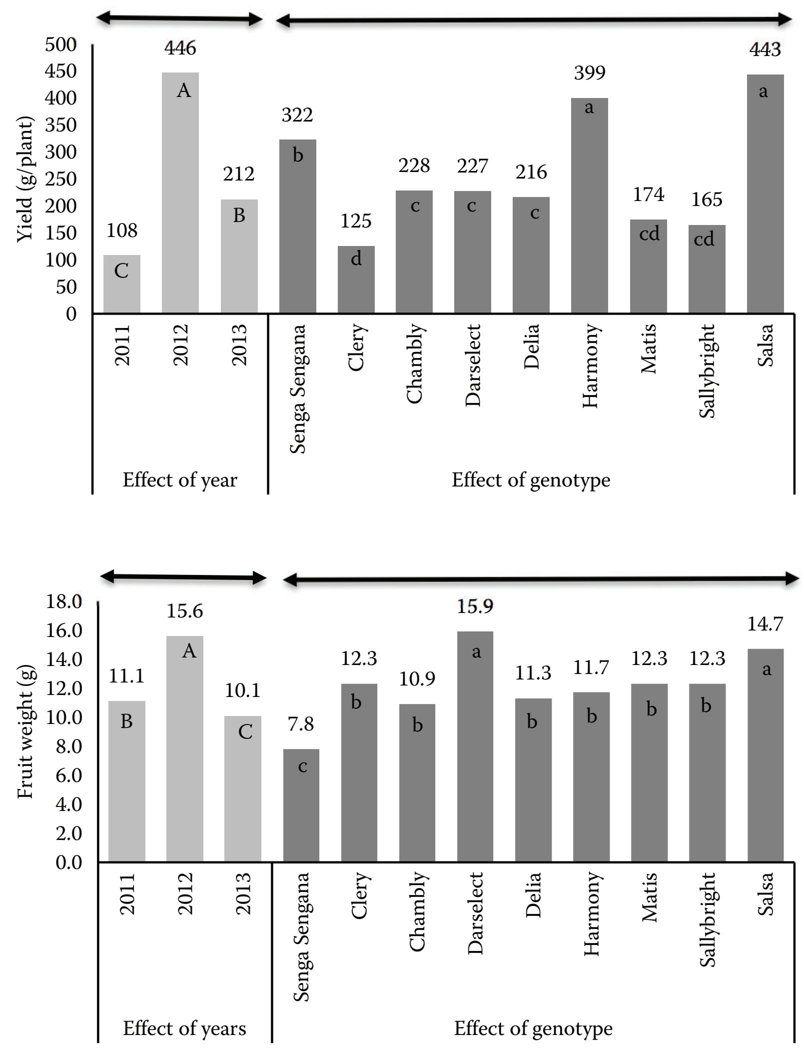

Fig. 1. Effect of year and strawberry genotypes on (a) average yield and (b) fruight weight over the three years different letters in figures mark significant differences at $P \leq 0.05$

Table 3. Mean, maximum and minimum temperatures and precipitation from April to July of 2011–2013 (data withdrawn from field weather station)

Year	Month	Mean temp (°C)	Max. temp (°C)	Min. temp (°C)	Precipitation (mm)
2011	April	6.3	21.1	–3.7	13.8
	May	10.8	27.4	–4.8	61.0
	June	19.0	29.0	7.0	0.6
	July	20.4	25.4	0.7	66.0
2012	April	4.9	18.5	–8.3	80.6
	May	11.3	23.5	–1.7	66.2
	June	13.0	23.7	1.6	50.8
	July	17.5	31.2	7.7	35.2
2013	April	3.4	16.0	–11.9	80.4
	May	14.0	27.9	–1.8	80.4
	June	17.4	30.0	5.6	35.2
	July	17.1	28.2	6.6	60.0

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Table 4. Biochemical composition of strawberry fruits

Genotype	Brix°	Sugars (%)	Organic acids (%)	Sugars/ acids	Ascorbic acid (mg/100 g)
Senga Sengana	10.8[abc]	6.3[c]	1.7[a]	3.8[d]	64[bc]
Clery	12.0[a]	8.3[a]	1.4[cd]	5.9[a]	70[bc]
Chambly	10.8[abc]	6.8[bc]	1.5[bc]	4.6[bc]	85[ab]
Darselect	10.7[abc]	6.2[c]	1.3[d]	4.7[bc]	81[ab]
Delia	9.4[cd]	6.1[c]	1.5[bc]	4.1[cd]	63[bc]
Harmonie	10.4[bc]	5.8[c]	1.5[bc]	4.0[cd]	97[a]
Matis	8.6[d]	5.8[c]	1.6[ab]	3.7[d]	48[c]
Sallybright	11.0[ab]	7.9[ab]	1.7[a]	4.8[b]	97[a]
Salsa	9.7[bcd]	6.4[c]	1.4[cd]	4.6[bc]	70[bc]

different letters in columns mark significant differences at $P \leq 0.05$

southern sites. In the trials of Crespo et al. (2010) in Switzerland, Brix° of 'Clery' was somewhat lower than in our trial. Brix° of 'Salsa' in Poland (Masny, Żurawicz 2009) was almost the same as in our trial. The sugar content was relatively low in the fruits of all the genotypes except 'Clery' and 'Sallybright' (Table 4). The acid content in the fruits was higher in 2011 than in 2012. In both years, the fruit of genotype 'Darselect' contained the least amount of acids and the fruit of 'Senga Sengana' and 'Sallybright' the highest amount. In the Swiss trials (Crespo et al. 2010), the acid content of 'Clery' and other strawberry genotypes was considerably lower than in ours. In the majority of genotypes, sugar and acid ratio in fruit was the highest in 2011, only the genotypes 'Darselect', 'Harmonie' and 'Sallybright' had a higher ratio in 2012. The highest sugar/acid ratio was in genotype 'Clery' and the lowest in 'Matis' and 'Senga Sengana' (Table 4). Fresh strawberry fruits are a remarkable source of ascorbic acid. In the majority of the tested genotypes, the content of ascorbic acid was higher in 2011 than in 2012, the fruit of 'Darselect' and 'Clery' contained more ascorbic acid in 2012. The differences between years were rather large. The average content of ascorbic acid in the fruit was the highest in genotypes 'Sallybright' and 'Harmonie'. 'Salsa' grown in Poland (Masny, Żurawicz 2009) had a higher ascorbic acid content but the fruit of 'Salsa' grown in Austria (Spornberger et al. 2008) had a lower ascorbic acid content than in our trial.

Better genotypes for Estonian climate conditions are the winter hardy, late-yielding cultivars 'Salsa' and 'Harmonie'.

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