BIOLOGIJA. 2008. Vol. 54. No. 2. P. 101–104
DOI: 10.2478/v10054-008-0020-x

Evaluation of the morphological, physiological and biochemical parameters of edible carrot (*Daucus sativus* Röhl.)

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In 2005–2006, at the Lithuanian Institute of Horticulture there were investigated and evaluated three cultivars of edible carrot of Lithuanian selection ('Garduolės', 'Šatrija', 'Vaiguva'), two hybrids ('Svalia' F_1, 'Skalsa' F_1) and five perspective breeding numbers (1680 F_1, 2031 F_1, 2030 F_1, 1859 F_1, 2049 F_1). The hybrid 'Svalia' accumulated the biggest amount of carotene (26.2 mg 100 g^{-1}), less nitrates (173.7 mg kg^{-1}) and had a good storability (86.1%) of their root-crops during winter time. The perspective breeding number 2030 F_1 was productive (total yield – 64.0 t ha^{-1}), its root-crop shape was nice-looking (length 18.9 cm and diameter 4.1 cm) and their storability during winter time reached 88.7%.

Key words: biochemical composition, carrots, morphological indices, productivity, storage of root-crop

INTRODUCTION

Lithuanian agroclimatic conditions are favourable for carrot growing. The nutritional carrot value is very important not only because of good dietetic properties, but also because of provitamine A-β carotene in them. It is possible to increase their yield by agrotechnical means, so carotene content is determined rather by the genetic nature of a cultivar [1]. Lately there are very popular heterosic carrot hybrids of the first generation, which under conditions of high agrotechnique are more productive and qualitative than cultivars. Carrot hybrid breeding in Lithuania was started in 1985; before, sterile analogues of cultivars had been created [2]. There were created carrot hybrids 'Svalia' and 'Skalsa' [3, 4]. Carrot cultivars, hybrids and breeding numbers were distinguished for the content of carotene, productivity and resistance to diseases [5–9].

The aim of the work was to investigate the productivity of edible carrot cultivars, hybrids and breeding numbers, to evaluate the morphological parameters of root-crops, the biochemical composition and storability of their root-crops during winter, and to select the most valuable samples for trade horticulture.

MATERIALS AND METHODS

In 2005–2006, at the Lithuanian Institute of Horticulture there were investigated and evaluated three edible carrot cultivars of Lithuanian selection ('Garduolės', 'Šatrija', 'Vaiguva'), two hybrids ('Svalia' F_1, 'Skalsa' F_1) and five perspective breeding numbers (1680 F_1, 2031 F_1, 2030 F_1, 1859 F_1, 2049 F_1).

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Investigations were carried out in a crop rotation of the experimental field. The soil was sandy light loamy calcaric epihypogleyic luvisol (IDg 8-k./Calc (ar)i – Epihypogleyc Luvisols – LVg-p-w-cc) [10]. Carrot sowing was carried out by a manual sowing machine on the profiled surface in two rows, with inter-rows of 70 cm, in the second decade of May. The experiment was carried out in three replications. During investigations, ten root-crops from each replication were evaluated to establish their morphological parameters (length, diameter, weight). The total and marketable yields from one hectare were calculated. After harvesting, we used five root-crops in three replications to establish the total content of sugar (Bertran's method), carotene (Murri's method) [11] and nitrates (by potentiometry) [12] at the laboratory of Biochemistry and Technology.

Carrot root-crops were stored during winter in a stationary cellar till 25 March, at a temperature from +2 to +7 °C, relative humidity 90–95%.

The morphological traits, yield data and biochemical composition were processed by STAT ENG and ANOVA computer programs [13].

For analysis of all system of correlations among the traits we used the principal component method [14]. By the method of principle co-ordinate analysis and the Unscrambler computer program we established the layout of the edible carrot cultivars, hybrids and numbers in a two-dimensional space according to productivity and root-crop storage in 2005–2006.

The meteorological conditions during the years of investigation were uneven. In the spring of 2005 the dryer and colder air prevailed. Carrots germinated unevenly, but in the middle of vegetation and up to the harvesting grew evenly. In August there was more precipitation (109.4 mm), but the weather was cooler and this influenced carrot root-crop quality and yield.

In 2006, precipitation at the beginning of May and the warm weather caused a better carrot germination. Later on, carrots lacked humidity, especially in June when the precipitation was only 13.8 mm. More quickly carrot began to grow in August.

RESULTS

Carrot hybrids must be distinguished not only for a good external and internal quality, but also for marketable appearance and productivity. The evaluation of carrot yield and its structural elements showed that the carrot cultivar 'Garduolės' react less to environmental conditions (Table 1). Carrots 2030 F_1 were distinguished for the biggest total yield, and this perspective breeding number made up 86.1% of marketable root-crops.

The most popular carrot cultivars and hybrids in Lithuania are those in which root-crops are of even form, approximately 18–22 cm in length and 3.6–4.1 cm in diameter. During the years of investigation, carrots 'Garduolės' 'Šatrija', 'Svalia' F_1 and 2030 F_1 corresponded to the requirements best. The carrot hybrid 'Svalia' was distinguished for the smallest root-crops (the average weight of marketable root-crops is 122.9 g).

When growing carrots, their nutritional properties are very important. The content of carotene and total sugar in them is one of the main quality parameters. The evaluation of carrot root-crop biochemical composition showed that Lithuanian cultivars and hybrids accumulated 18.0 to 26.2 mg 100 g^{-1} of carotene (Table 2). Carrots of the cultivar 'Vaiguva' in the years of study had the largest content of sugar (10.6%), while the sugar content in number 2049 F_1 carrots was very low (6.5%). Therefore, these carrots might be used in breeding as donors according to the total sugar. Root-crops of carrots 'Svalia' F_1 had high biochemical indices. The carrots of this hybrid accumulate little nitrates (173.7 mg kg^{-1}) and much carotene (26.2 mg 100 g^{-1}).

In carrot breeding, when creating cultivars and hybrids, a lot of attention is paid to the indices of carrot productivity and physiology. One of carrot physiological indices is root-crop storability during winter (Table 3). Our investigations showed that the hybrid number 2030 was distinguished by the marketable production and good winter storability (88.7 ± 1.3%). Under favourable storage conditions (temperature approximately +2 to +7 °C and humidity 90–95%) carrots do not loss their quality. Our investigations have shown that under such conditions it is possible to preserve 70.0–88.7% of root-crops. According to the data of two years, root-crops of the study samples were more injured by phomo-

Table 1. **Evaluation of the productivity and morphological parameters of edible carrot**

Cultivars, hybrids, number	Total yield, t ha^{-1}	Output of marketable yield, %	Root-crop morphological indices		
			Length, cm	Diameter, cm	Weight, g
'Garduolės'	59.6	80.3	19.4	3.6	168.8
'Šatrija'	56.2	77.0	20.8	3.6	169.8
'Vaiguva'	51.0	74.1	16.5	4.6	179.4
'Svalia' F_1	60.2	79.9	19.2	3.6	122.9
'Skalsa' F_1	53.0	70.6	15.8	4.1	170.7
1859 F_1	49.7	88.3	16.5	3.9	160.9
1680 F_1	58.2	76.3	17.2	3.3	148.7
2030 F_1	64.0	86.1	18.9	4.1	152.5
2031 F_1	58.5	74.4	16.8	3.8	149.1
2049 F_1	61.4.	80.1	18.1	3.5	164.8
LSD_{05}	8.28		1.26	0.24	8.13

Table 2. **Carrot root-crop biochemical indices**

Cultivars, hybrids, number	Carotene, mg $100g^{-1}$	Total sugar, %	Nitrates, mg kg^{-1}
'Garduolės'	21.4	9.3	269.1
'Šatrija'	21.3	8.7	270.1
'Vaiguva'	21.7	10.6	223.7
'Svalia' F_1	26.2	9.1	173.7
'Skalsa' F_1	24.9	9.0	264.4
1859 F_1	21.7	9.3	395.4
1680 F_1	20.9	8.0	211.9
2030 F_1	23.6	8.7	209.4
2031 F_1	18.0	8.6	219.3
2049 F_1	22.4	6.5	234.7
LSD_{05}	3.27	2.24	79.59

Table 3. **Statistical analysis of the marketable yield and root-crop storability of edible carrot**

Cultivars, hybrids, number	Marketable yield, t ha^{-1}			Root-crop storage, %		
	M S±	M_{min}-M_{max}	V, %	M S±	M_{min}-M_{max}	V,%
'Garduolės'	47.8 ± 1.1	45.60–49.00	4.04	83.6 ± 3.0	77.80–88.00	6.27
'Šatrija'	43.3 ± 3.9	37.00–50.50	15.72	79.0 ± 0.6	78.00–80.00	1.27
'Vaiguva'	37.8 ± 0.9	36.00–39.30	4.40	70.0 ± 1.2	68.00–72.00	2.86
'Svalia' F1	48.1 ± 1.6	45.00–50.00	5.63	86.1 ± 2.0	83.30–90.00	4.05
'Skalsa' F1	37.4 ± 2.5	33.80–42.10	11.43	72.9 ± 2.9	70.00–78.60	6.81
1859 F1	43.9 ± 1.0	42.30–45.80	4.03	76.6 ± 1.2	75.00–79.00	2.79
1680 F1	44.4 ± 2.5	40.30–48.90	9.72	80.3 ± 0.9	78.80–82.00	2.01
2030 F1	55.1 ± 2.8	49.90–59.30	8.66	88.7 ± 1.3	86.00–90.00	2.60
2031 F1	43.5 ± 2.9	40.30–49.30	11.50	77.7 ± 1.4	75.00–80.00	3.24
2049 F1	49.2 ± 3.2	44.30–55.30	11.35	75.0 ± 2.9	70.00–80.00	6.67
LSD05	8.24			5.88		

M S± – mean and standard error; Mmin – Mmax – the range of mean values within accessions; V – coefficient of variation.

sis and alternariosis (affected by soft rot) than by dry rot which is caused by bacteria. It is possible to state that the root-crops of these carrots are resistant to dry rot, because in spring there were no injured ones.

DISCUSSION

Investigations showed that the internal and external quality of vegetable depends not only on the genotype, but also on soil and growth conditions [15]. Years 2005–2006 were favourable for carrot growing. During the intensive growth of root-crops, carrots need constant humidity, because its lack worsens root-crop quality and resistance to rots during carrot storage [16]. In the study years, carrots produced qualitative root-crops typical of this cultivar; their storability in winter was good.

Edible carrots in a two-dimensional space of different cultivars, hybrids and perspective the hybrid number according to the results of principle coordinates (PK) could be classified into several small groups (Figure). One group comprised cultivars and hybrids whose marketable yield reached 36.5 to 42.7 t ha^{-1} (Figure, a). Cultivar 'Garduolės', hybrid 'Svalia' and hybrid numbers 2030, 2049 took place in one PK and were distinguished by a high productivity. Comparison of the results of carrot root-crop winter storability according to the PK analysis, showed that the root-crop storability of cultivar 'Vaiguva' was the poorest (70%). The storability of carrots 'Svalia' F_1 and 2030 F_1 was good (Figure, b). 'Svalia' F_1, 'Garduolės', hybrid number 2030, which in the PK space took a highly positive value, allow for practical purposes to select under Lithuanian climatic conditions the most valuable breeding samples that would be suitable for marketable horticulture.

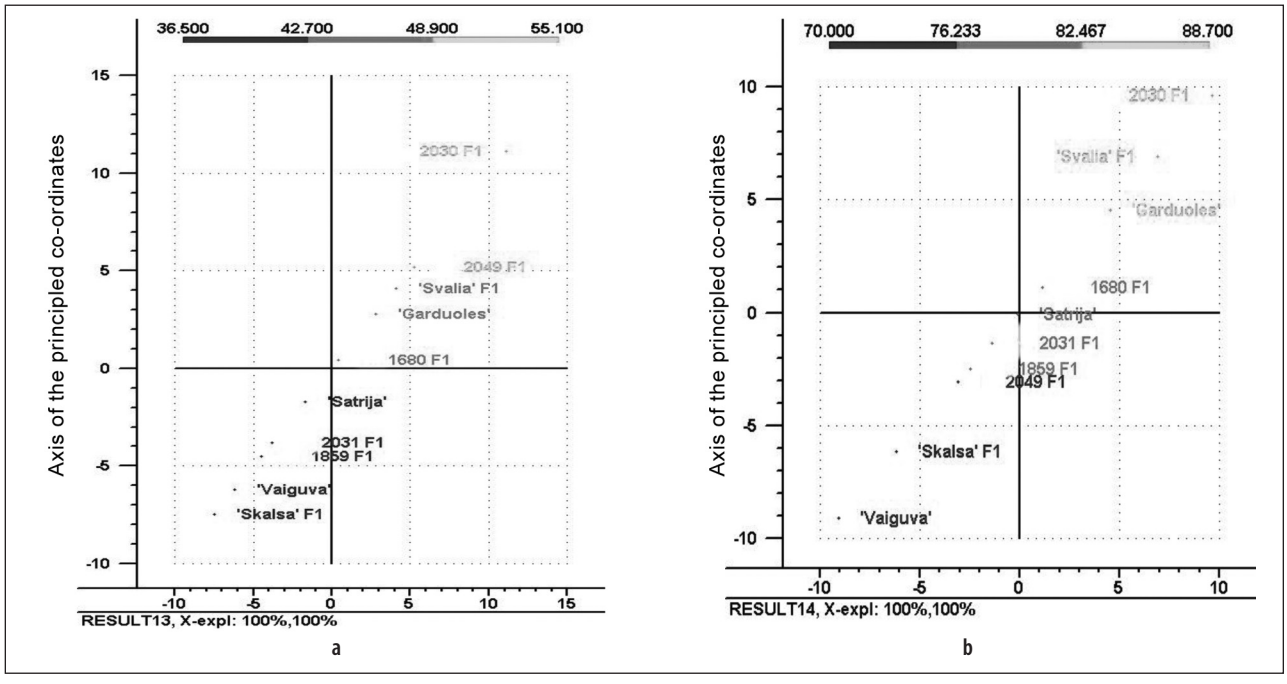

Figure. The layout of various edible carrot cultivars, hybrids and numbers in a two-dimensional space according to the results of principled co-ordinate analysis (PK) of productivity data (marketable yield, t ha^{-1}) (a) and storage (%) (b)

ACKNOWLEDGEMENTS

We are grateful to the Ministry of Education and Science for support within the programme "Scientific Researches of Plant Genetic Resources 2004–2008".

Recived 26 January 2008
Accepted 22 April 2008

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Santrauka

2005–2006 m. Lietuvos sodininkystės ir daržininkystės institute tirtos ir įvertintos trys lietuviškos selekcijos valgomosios morkos veislės – 'Garduolės', 'Šatrija', 'Vaiguva' du hibridai – 'Svalia' F_1, 'Skalsa' F_1 ir penki perspektyvūs selekciniai hibridiniai numeriai – 1680 F_1, 2031 F_1, 2030 F_1, 1859 F_1, 2049 F_1. Nustatyta, kad morkų hibridas 'Svalia' sukaupia daug karotino (26,2 mg 100 g^{-1}), mažai nitratų (173,7 mg kg^{-1}), 86,1% šakniavaisių išsilaiko per žiemą. Perspektyvus selekcinis numeris 2030 F_1 yra derlingas (bendras derlius – 64,0 t ha^{-1}), pasižymi gražios formos šakniavaisiais (18,9 cm ilgio ir 4,1 cm skersmens), 88,7% jų išsilaiko per žiemą.