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Productivity and adaptability of the new carrot and garlic cultivars in Lithuania

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Abstract

The new carrot (*Daucus sativus* Röhl.) hybrids 'Ieva' and 'Rokita' and the garlic (*Allium sativum* L.) cultivar 'Dangiai' were developed at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry during 2012–2015. The breeding direction was to increase vegetable production and to improve its quality. Carrot roots of the new hybrids have good properties for storage and maintenance of biochemical components. The hybrids 'Ieva' and 'Rokita' were compared with three foreign hybrids 'Jitka', 'Maestro' and 'Champion'. Lithuanian hybrids were distinguished by the highest marketable yield ranging from 64.6 to 66.7 t ha^{-1}. The hybrid 'Ieva' accumulated the highest content of carotene 21.8 mg 100 g^{-1}, total sugar 8.6% and dry soluble solids 11.5%. Roots of the hybrid 'Rokita' were the most resistant to black rot of carrots and bacterial soft rots. Good adaptability, productivity and a stable number of cloves per bulb is characteristic of the new garlic cultivar 'Dangiai'. The overwinter survival rate of plants was 98%, the productivity – 14.6 t ha^{-1} and the average weight per bulb – 75 g.
The carrot hybrids 'Ieva' and 'Rokita' and the garlic cultivar 'Dangiai' have been included in the National Plant Variety List and in the EC Common Catalogue of Varieties of Vegetable Species.

Key words: *Allium sativum*, breeding, *Daucus sativus*, garlic, heterosis, selection.

Introduction

Changing of climatic conditions, economic factors and social environment emphasize the need for the development of new and effective cultivars. Successful cultivar development depends on the availability of genetic material, knowledge of important plant traits and methods of breeding (Volk, Stern, 2009; Sasnauskas et al., 2012; Karklelienė et al., 2014; Navazio, Zystro, 2014; Ayalew et al., 2015; Bradshaw, 2016; Sasnauskas et al., 2017).

Carrot and garlic are an important vegetable species taking one of the main positions in Lithuania. The breeding programmes of these vegetables at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry are focused on the productivity, resistance to diseases and the adaptability to local agro-climatic conditions (Gaučienė, Viškelis, 2001; Survilienė, Valiuškaitė, 2006; Karklelienė, Bobinas, 2009; Karklelienė et al., 2012). The selection of parental plants according to specific characteristics is very important for achieving heterosis effect in the progenies. When the inheritance of traits is known, it is possible to effectively select genotypes that are necessary for the creation of carrot hybrids and to prognosticate the parameters of hybrids. This is important for speeding up the carrot breeding process (Karklelienė, Bobinas, 2009; Bradshaw, 2016). Cytoplasmic male sterility (CMS) analogy of Lithuanian carrot cultivars distinguishing by the productivity and biochemical compounds have been crossed with the constant cultivars distinguishing by the optimal morphological features.

In spite of increasing garlic production and productivity, the yield is low in many parts of the world due to genetic and environmental factors affecting the yield and yield related traits (Nonnecke, 1989; Ahmed et al., 2007; Mahadeen, 2011). Garlic, being an asexually propagated crop, has limited variability. Breeders depend upon natural clonal mutations and selection of the best clones from the germplasm (Lawande et al., 2009).

The aim of the research was to introduce the new Lithuanian carrot hybrids and garlic cultivar and to compare them with the cultivars of other countries.

Materials and methods

Investigations were carried out in the crop rotation experimental field at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry in 2010–2015. The soil of the experimental site is a

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Calcic Endogleyic Luvisol (*LV-gl-n-cc)* (WRB, 2014) light loam. Sowing, planting, fertilization, weeding, chemical plant protection was carried out according to the scientific methods for agriculture and forestry research investigations (Uselis et al., 2013).

Carrot (*Daucus sativus* Röhl.). The two new Lithuanian hybrids 'Ieva' and 'Rokita' were compared with foreign hybrids of different genetic origin: 'Jitka' (Czech Republic), 'Maestro' (France) and 'Champion' (The Netherlands). In our research, all the tested hybrids presented the vegetation period from 120 to 135 days. Carrot roots are suitable for the autumn harvest and storage.

The new carrot hybrids of the first generation were developed by crossing the lines with cytoplasmic male sterility (CMS) and constant lines. Two new hybrids 'Ieva' and 'Rokita' belonging to the Nantes type were developed at this stage. The carrots were sown within the first ten-day period of May in 2012–2015 by a hand-operated seeding machine on a profiled surface, in two rows with 70 cm inter-rows. The carrots were harvested within the last ten-day period of September in all years of investigation. Biochemical parameters were established in fresh weight (FW) at the Laboratories of Plant Physiology and Biochemistry and Technology of Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry. Carotene in carrots was measured by Murri method (Ермаков, 1987), the amount of total sugar by Bertrane method, dry soluble solids by a numeric refractometer (AOAC, 1990 a; b). Ten carrot roots were selected per each replication for long term storage in controlled-climate chambers at ±1°C temperature and 85–90% humidity. The experiment was carried out in three replications. Pathogen damage to carrots was evaluated during storage in October–March according to the standard methodology; visual-symptomatic methods were applied for the disease diagnostics. Root pathogen damage was calculated.

Garlic (*Allium sativum* L.). The new cultivar 'Dangiai' representing hardneck morphotype has been developed by applying individual and mass selection. Eight garlic cultivars of different origin were investigated in the studies: 'Dangiai' (breeding number No. 24) and 'Žiemiai' (Lithuania), 'J. Gribovo' (Russia), 'Ducat' and 'Unicat' (Czech Republic), 'Liubasha' (Ukraine), 'Teodor' (Germany) and 'Spring Violeta' (Spain).

Cloves of garlic with an average weight of 6–7 g were planted within the last ten-day period of October (in 2012, 2013 and 2014). Planting of cloves was carried out by hand in 1 m wide furrows. Distances of 30 cm between rows and 7 cm between plants were left. The area of record plot was 0.7 m². The experiment was carried out in three replications. Experimental plot was covered with the peat mulch. Garlic bulbs were harvested within the second ten-day period of July in 2013, 2014 and 2015, when 30–50% of the lower leaves had dried. Bulbs were dried using active ventilation for about two weeks. After drying, bulbs were grated into two size fractions and the total yield of garlic and its structure were determined. Marketable yield consisted of well developed, high quality bulbs with a diameter of more than 4 cm. Ten marketable bulbs were weighed for the determination of an average weight per bulb. Number of cloves per bulb, arrangement and skin colour of 5 representative bulbs of each cultivar were estimated according to the guidelines for distinctness, uniformity and stability (DUS) test. Macro- (K, Ca) and micro- (S, Mg) elements were analysed in the garlic cultivar 'Dangiai' bulbs in the middle of July. For element analysis, 0.4 g of bulb tissue was digested with 6 ml HNO_3 and 2 mL H_2O_2 in a microwave digestion system Multiwave GO (Antor Paar GmbH, Austria) according to Marin et al. (2011). The resulting solutions were cooled and diluted to 50 mL with distilled water and analysed by ICP-OES Spectro Genesis (Spectro Analytical Instruments GmbH, Germany). Winter hardiness of garlic was evaluated at the beginning of intensive growth of leaves in the 3rd ten-day period of April. The percent of survived plants was calculated.

The data of yield and biochemical parameters were statistically processed by the analysis of variance (*ANOVA*) according to Duncan's multiple range for mean separation at 5% significance level (Raudonius, 2017).

Meteorological conditions. The average temperature of May in 2012 was 11.8°C and the amount of rainfall was 57.8 mm this month. The highest temperature (+18.7°C) and the maximum amount of rainfall was in July in this year. In September the temperature and amount of rainfall were close to the multiannual average. The mean temperature was 5.4°C and 4.9°C in October in 2013 and 2014, respectively the amount of precipitation was 45.2 and 48.8 mm. In November, the temperature was 2.6°C and 3.8°C, and the amount of precipitation was 45.8 and 43.3 mm, respectively. The mean temperature of April in 2014 and 2015 had not exceeded 8.1°C. The air temperature in May and June in both years was similar, but July and August in 2014 was higher 3-5 °C than in 2015. The amount of precipitation was more than twice higher in 2014 than in 2015. June was dry in 2015, but there was frequent rain in July.

Results and discussion

Carrot. The marketable yield of carrots during the experimental years varied from 44.2 to 70.5 t ha^{-1} and marketability from 80.6% to 96.6%, respectively (Table 1). The new hybrids 'Ieva' and 'Rokita' in average four-year data, produced the significantly highest marketable yield 66.7 and 64.6 t ha^{-1} compared with the hybrids 'Jitka' and 'Maestro'. The marketable yield 60.4 t ha^{-1} of hybrid 'Champion' in average four-year data was obtained similar to Lithuanian hybrid 'Rokita'. In 2014 year, when the average temperature in July and August was 20.4–23.2°C degrees and the precipitation amount was enough, carrots formed a higher yield (54.0–70.5 t ha^{-1}) than in the all year of investigation.

Biochemical composition shows quality of carrot root. Grune et al. (2010) confirmed that carotenoids, including α- and β-carotene, are abundant in carrots. They account for both high provitamin A content and orange colour of roots. One of the main properties is the amount of carotene in them. Baranski et al. (2012) have reported that total carotenoid content is related to root colour and range from 0 to 40 mg 100 g^{-1} FW. According to our data of the two-year studies, the roots of the new hybrid 'Ieva' accumulated the highest amount of carotene 21.2–23.0 mg 100 g^{-1} (Table 2). Lithuanian hybrids 'Ieva' and 'Rokita' accumulated significantly the highest amount of the total sugar 8.6% and 8.3%, respectively compared to the carrot hybrids from other countries. The amount of dry soluble solids in the hybrids 'Ieva' and 'Rokita' was similar (11.3–11.7%) and significantly higher than in other countries.

Table 1. Productivity of carrot hybrids in 2012–2015

Hybrid	2012	2013	2014	2015	2012–2015 average
			Marketable yield t ha^{-1}		
Ieva	63.5 bcd	67.9 d	70.5 d	64.6 c	66.6 d
Rokita	64.8 d	67.9 d	65.1 bcd	60.6 bc	64.6 bcd
Jitka	46.3 a	44.2 a	54.0 a	48.2 a	48.2 a
Maestro	51.2 a	51.2 ab	58.3 ab	52.0 a	53.2 a
Champion	58.0 b	58.4 b	62.8 bcd	62.4 bc	60.4 b
			Marketability %		
Ieva	90.5	92.0	96.6	93.7	93.2
Rokita	89.8	91.0	94.5	92.7	92.0
Jitka	80.6	87.4	92.5	89.5	87.5
Maestro	84.5	88.1	93.0	90.0	88.9
Champion	87.5	88.5	94.2	90.2	90.1

Note. Means followed by the same letter do not differ significantly within the column at $P = 0.05$ (Duncan's multiple range test).

Table 2. The biochemical properties of roots (fresh weight) of carrot hybrids in 2013–2014

Hybrid	Carotene mg 100 g^{-1}			Dry soluble solids %			Total sugar %		
	2013	2014	2013–2014 average	2013	2014	2013–2014 average	2013	2014	2013–2014 average
Ieva	21.2 e	23.0 d	21.8 d	11.4 c	11.7 c	11.5 c	8.5 d	8.7 c	8.6 c
Rokita	19.9 d	20.9 c	20.2 c	11.3 c	11.6 bc	11.4 c	8.3 bcd	8.4 bc	8.3 bc
Jitka	18.2 c	19.4 b	18.6 b	9.3 a	10.5 abc	9.7 a	7.0 a	8.0 abc	7.5 a
Maestro	16.6 b	17.0 a	16.7 a	9.5 a	9.8 a	9.6 a	7.8 b	8.2 abc	8.0 abc
Champion	15.5 a	16.6 a	15.9 a	9.7 a	10.0 a	9.8 a	7.2 a	7.4 a6	7.3 a

Explanation under Table 1

Our investigation showed that carrots stored till the 1st ten-day period of April were damaged by pathogenic fungi and bacteria. Lewis and Garrod (1983) found that carrots were the most vulnerable to pathogenic fungi: *Phoma* sp. (dry rot), *Sclerotinia sclerotiorum* (sclerotinia rot) and bacteria (bacterial soft rot). Modern strategies of black rot and bacterial soft rot control involve multiple methods, including planting of pathogen free seed, seed testing, seed treatments, crop rotation, scouting, computer forecasting models, applications of fungicides, and appropriate postharvest handling of carrots (Farrar et al., 2004; Survilienė, Valiuškaitė, 2006; Boedo et al., 2010; Collier et al., 2017). Results in the Table 3 show that hybrid 'Jitka' root-crops were the most susceptible (6.0–9.4%) to black rot of carrots and bacterial soft rot (2.5–4.0%) damage. The new hybrids 'Rokita' and 'Ieva' were observed as the most resistant. Our investigation proved that Lithuanian hybrids of carrot are well adapted to local conditions and are resistant to biotic and abiotic factors.

Table 3. Damage by diseases in carrots during storage in 2013–2014

Hybrid	Damage by diseases %					
	black rot			bacterial soft rot		
	2013	2014	2013–2014 average	2013	2014	2013–2014 average
Ieva	1.0 b	0 a	1.0 a	0 a	0 a	0 a
Rokita	0 a	0 a	0 a	0 a	0 a	0 a
Jitka	9.4 d	6.0 c	7.7 c	2.5 d	4.0 d	3.0 d
Maestro	0.9 b	0.7 a	0.8 a	0.5 b	1.5 b	1.0 b
Champion	5.0 c	3.0 b	4.0 b	1.0 c	3.0 c	2.0 c

Explanation under Table 1

Garlic. Different meteorological conditions in winter during the investigation period 2012–2015 provided a possibility to estimate the winter hardiness of cultivars. The unfourable conditions for garlic were from the beginning to mid of January in 2015, when the snow cover was either very thin or absent and the air temperature below −20°C lasted. Both Lithuanian cultivars showed the highest winter hardiness. The overwinter survival rate reached from 96.3% to 98.0% (Table 4).

The other cultivars were less resistant and the amount of survived plants reached from 65.0% to 90.3%, except for 'J. Gribovo' (93.6%). Our results agree with those of other authors that garlic is very sensitive to the climatic conditions (Waterer, Schmitz, 1994; Volk, Stern, 2009). The findings of Kamenetsky et al. (2004) confirmed that the environmental factors such as temperature influenced garlic development and growth.

Consumers prefer garlic bulbs with light coloured of external scale, and desirable diameter of bulb is above 4 cm in Lithuania. Results of investigation showed that Lithuanian cultivars 'Žiemiai' and 'Dangiai' significantly distinguished by the highest productivity among the tested cultivars in all year of investigation. The total yield reached from 13.9 to 14.6 t ha^{-1} (Table 5). Average results

Table 4. Winter hardiness (%) of garlic in 2012–2015

Cultivar	2012–2013	2013–2014	2014–2015	Average 2012–2015
Žiemiai	100	100	89	96.3
Dangiai	100	99	95	98.0
J. Gribovo	98	98	85	93.6
Unicat	95	84	69	82.6
Ducat	96	82	61	79.6
Liubasha	95	95	81	90.3
Spring Violeta	80	75	40	65.0
Teodor	89	85	72	82.0

Table 5. Garlic productivity in 2013–2015

Cultivar	Total yield t·ha^{-1}				Marketability %			
	2013	2014	2015	2013–2015 average	2013	2014	2015	2013–2015 average
Žiemiai	12.9 b	14.7 ab	14.2 a	13.9 a	98	99	97	98.0
Dangiai	14.4 a	15.4 a	14.0 a	14.6 a	98	97	96	97.0
J.Gribovo	13.5 ab	13.4 b	12.1 b	13.0 ab	98	98	95	97.0
Unicat	8.9 c	8.5 cd	6.0 d	7.8 c	96	94	84	91.3
Ducat	10.3 b	9.4 c	6.5 d	8.7 c	96	96	85	92.3
Liubasha	14.6 a	13.5 b	10.2 c	12.8 b	98	98	92	96.0
Spring Violeta	6.9 d	6.0 e	3.2 f	5.4 d	93	90	85	89.3
Teodor	10.7 b	9.9 c	5.3 de	8.6 c	93	88	86	89.0

Explanation under Table 1

of yield showed that the productivity cultivar 'Dangiai' was 0.7 t ha^{-1} higher that 'Žiemiai'. The both cultivars produced high output of marketable yield.

The cultivar 'Dangiai' formed significantly heavier bulbs. The average bulb of 'Dangiai' weighed 75.3 g (Table 6). The number of cloves per bulb was stable (7) in all years of investigation. Our results as well as those of other researchers suggest that the number of cloves is determined genetically. Mahadeen (2011) reported that cloves smaller than 1 g produced the least number of cloves, but Ahmed et al. (2007) disagreed with it.

Table 6. Garlic morphological features in 2013–2015

Cultivar	Average weight of bulb g				Number of cloves				Colour of bulb external scales
	2013	2014	2015	2103–2015 average	2013	2014	2015	2013–2015 average	
Žiemiai	68 b	66 bc	54 c	62.7 c	12 a	11 a	10 a	11.0 a	white
Dangiai	79 a	78 a	69 a	75.3 a	7 bc	7 bc	7 bc	7.0 bc	cream purple
J.Gribovo	72 b	71 b	68 a	70.3 ab	8 b	8 b	8 b	8.0 b	purple
Unicat	63 c	65 c	50 c	59.3 c	9 b	8 b	7 bc	8.0 b	purple
Ducat	66 bc	64 c	59 b	63.0 c	8 b	7 bc	6 c	7.0 bc	cream
Liubasha	75 a	71 b	65 a	70.3 ab	9 b	8 b	9 a	8.6 ab	purple
Spring Violeta	55 d	50 d	43 d	49.3 d	9 b	9 b	6 c	8.0 b	purple
Teodor	64 c	61 c	55 b	60.0 c	10 ab	10 ab	10a	10.0 a	white

Explanation under Table 1

Garlic takes one of the most significant places among the vegetables that benefit human health (Ayalew et al., 2015; Bi Bi Mariam, Usha Devi, 2016). A garlic bulb is composed mainly of water. According to literature the amount of water reaches 60–75% in the composition of a fresh bulb (Ayalew et al., 2015; Leyva et al., 2016). Our study showed that cultivar 'Dangiai' contains 22.4% (6.31 g) of dry matter. Ayalew et al. (2015) reported similar dry matter values varying from 15.3% to 25.8% of the local cultivars in Ethiopia. Sulphur is one the most important bioactive compounds of garlic bulb chemical composition. The amount of sulphur of cultivar 'Dangiai' reached 628.9 mg kg^{-1} FW. Analysis of other bioactive elements showed that the amount of potassium was 1806.5 mg kg^{-1} FW, calcium – 1415.82 mg kg^{-1} FW, sodium – 43.8 mg kg^{-1} FW, magnesium – 188.2 mg kg^{-1} FW.

Conclusions

1. The new Lithuanian carrot hybrids 'Ieva' and 'Rokita' and the garlic cultivar 'Dangiai' are well adapted to Lithuanian agro-climatic conditions. The hybrids and the cultivar are productive and resistant to biotic and abiotic factors.

2. The carrot hybrids 'Ieva' and 'Rokita' accumulated 20–22.5 mg % carotene; roots are of cylindrical pointed shape, medium in length (22–25 cm) and diameter (4.2–4.6 cm). Roots are suitable for harvesting in the autumn and for storage.

3. The garlic cultivar 'Dangiai' showed hardneck phenotype and were distinguished by high marketability and a stable number of cloves (7) per bulb. The amount of sulphur in the bulbs reached 628.9 mg kg^{-1}.

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Valgomosios morkos ir valgomojo česnako naujų veislių produktyvumas bei adapyvumas Lietuvoje

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Santrauka

Lietuvos agrarinių ir miškų mokslų centro Sodininkystės ir daržininkystės institute 2012–2015 m. buvo sukurti du nauji valgomosios morkos hibridai ‘Ieva’ bei ‘Rokita’ ir valgomojo česnako veislė ‘Dangiai’. Augalų selekcijos kryptis buvo didinti daržo augalų produktyvumą ir gerinti produkcijos kokybę. Naujų valgomosios morkos hibridų šakniavaisiai pasižymi geromis laikymosi savybėmis ir išsaugo biocheminius komponentus. Hibridai ‘Ieva’ ir ‘Rokita’ buvo palyginti su trimis užsienietiškais hibridais ‘Jitka’, ‘Maestro’ ir ‘Champion’. Lietuviški hibridai išsiskyrė didžiausiu prekiniu derliumi – nuo 64,6 iki 66,7 t ha^{-1}. Hibridas ‘Ieva’ sukaupė didžiausią kiekį – 21,8 mg 100 g^{-1} karoteno, 8,6 % suminio cukraus ir 11,5 % tirpių sausųjų medžiagų. Hibrido ‘Rokita’ šakniavaisiai buvo atspariausi juodajam ir bakteriniam morkų puviniams. Valgomojo česnako naujos veislės ‘Dangiai’ požymiai yra geras adaptyvumas, produktyvumas ir stabilus skiltelių skaičius ropelėje. Peržiemojusių augalų išeiga siekė 98 %, produktyvumas – 14,6 t ha^{-1}, ropelės vidutinis svoris – 75 g.
Valgomosios morkos hibridai ‘Ieva’ bei ‘Rokita’ ir valgomojo česnako veislė ‘Dangiai’ įtraukti į Nacionalinį augalų veislių sąrašą bei ES daržovių rūšių veislių bendrąjį katalogą.

Reikšminiai žodžiai: *Allium sativum*, atranka, *Daucus sativus*, heterozė, selekcija.