

Quality of organic and conventional carrots

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Abstract. At Jõgeva Plant Breeding Institute, cultivation of the Estonian carrot variety ‘Jõgeva Nantes’ conventionally (with application of mineral fertilizers: N 115, P 40 and K 152 kg ha⁻¹ and pesticides: Fenix, Actara 25 WG, Agil and Signum) and organically (compost, Humistar, agryl cover) was compared. Marketable yield of organic carrots was 11% higher than that of conventionally grown carrots. Conventional carrots contained pesticide residues and had significantly higher nitrate concentration than organic carrots. Contents of dry matter, total sugars, soluble solids, phosphorus, potassium, calcium and magnesium did not significantly differ between carrots between cultivation systems. The contents of β -carotene, vitamin C and nitrogen were significantly lower in organically grown than in conventionally grown carrot.

Key words: agryl cover, β -carotene, calcium, dry matter, magnesium, nitrogen, phosphorus, potassium, soluble solids, total antioxidant capacity, total sugars, vitamin C, yield

INTRODUCTION

In Estonia, as in other European countries, targets have been set to upgrade domestic organic production, including that of vegetables. This is driven by consumer demand to buy organic food primarily for health-related reasons. Preferred products are organic vegetables and fruits (Pehme et al., 2007). Therefore the quality of raw products is an important aspect. Quality of locally produced organic vegetables is still very poorly studied. Therefore the aim of the present study was to evaluate how the yield and quality of carrots is affected by production methods – organic versus conventional, according to principles of good agricultural practice.

MATERIALS AND METHODS

The field experiment was carried out at Jõgeva Plant Breeding Institute (26°24'E, 58°44'N) in 2008. Carrots were cultivated under conventional and organic conditions on plots of 100 m², with four replications of each treatment. For two years before the experiment, cereals were cultivated on the area according to the EU regulations on organic production (Council Regulation No. 843/2007). Soil at the site was classified as soddy-podzolic sandy loam. A soil sample was analysed before establishment of the experiment using the following methods: pH – ISO 10390, P, K, Ca, Mg, Cu, Mn – Mehlich III, B – by Berger and Truogi and C_{org} – by NIRS. The following results were

obtained: pH_{HCl} 6.1, P 65 mg kg⁻¹, K 121 mg kg⁻¹, Ca 1930 mg kg⁻¹, Mg 164 mg kg⁻¹, Cu 1.4 mg kg⁻¹, Mn 79 mg kg⁻¹, B 0.72 mg kg⁻¹ and C_{org} 1.7%. Hence the nutritional status of the soil was satisfactory and soil acidity favourable for carrot cultivation. No pesticide residues, as measured by the method prEN 15662: 2007 NIRS, were present in the soil. Both soil samples were analysed in Laboratory of Agrochemistry at the Estonian Agricultural Research Centre in Saku. For basic fertilization, 800 kg ha⁻¹ of Cropcare 8-12-23 (N 65, P 40, K 152 plus micronutrients) was applied to the conventional plot and 200 kg ha⁻¹ of compost (analysed by the Laboratory of Agrochemistry at the Estonian Agricultural Research Centre to have N 1.2%, P 0.26%, K 0.8%, pH_{HCl} 6.99) was applied to the organic plot. During the growing period conventional carrot plants were fertilized by ammonium nitrate (N 50 kg ha⁻¹) and sprayed with Folicare 18-18-18 (4 kg ha⁻¹), resulting in a total supply of 0.7 kg N, 0.3 kg P and 0.6 kg K ha⁻¹. Organic carrot plants were fertigated at a rate of 1 litre per meter of row with humic acids solution (fertilizer Humistar diluted by 1:20), resulting in a total supply of 1.4 kg K ha⁻¹. Carrot seeds of the Estonian variety 'Jõgeva Nantes' were sown on 27 May. The organic plot was covered after seed sowing for two months with non-woven polypropylene agryl cover to control carrot psyllid (*Trioza viridula*) and carrot fly (*Psila rosae*). The insecticide Actara 25 WG was sprayed at 120 g ha⁻¹ on 13 June and 30 July on the conventionally grown carrots. The soil of the conventional plot was treated with the herbicide Fenix at 2.5 l ha⁻¹ two days before the sprouting of carrots and 18 days after seed sowing against couch grass with a herbicide Agil 100 EC at 1.0 l ha⁻¹. The fungicide Signum 0.75 kg ha⁻¹ was used on 12 August to control black rot (*Alternaria radiciana*). The organic plot was weeded twice by hand and hoeing. The crops were harvested manually on 10 October. The following analyses were performed on one sample of raw carrot roots from each of the replicate organic and conventional plots: pesticide residues were analysed by gas chromatography in the Laboratory of Agrochemistry at the Estonian Agricultural Research Centre. Dry matter (DM), sugars and vitamin C were determined in the same laboratory; DM by 71/393 EEC method, total sugars using a method described by Faithfull (2002), vitamin C by a Murri's method as described by Turbas & Oll (1969). Soluble solids content (SSC) (°Brix) was measured using the digital refractometer ATAGO CO., Ltd., Japan. Total N was determined by Copper Catalyst Kjeldahl Method, (984.13); phosphorus by Stannous Chloride method, ISO/FDIS 15681, AN 5242; calcium by o-Cresolphthalein Complexone method, ISO 3696, AN 5260 in Kjeldahl Digest by Fiastar 5000; magnesium by Fiastar 5000, ASTN90/92 by Titan Yellow method; potassium by Flame Photometric Method, (956.01); nitrates by Fiastar 5000, AN 5201 (nitrate - N, Cd-reduction, ISO 13395), Foss Tecator AB, 2001 (Helrich, 1990). Total N, phosphorus, calcium, magnesium, potassium and nitrates were determined in the Plant Biochemistry Laboratory of Estonian University of Life Sciences. β -carotene was determined in the Health Protection Inspectorate Tartu Laboratory, using T44- HPLC method. Total antioxidant capacity (TAC) was determined using the 1.1-diphenyl-2-picrylhydrazyl (DPPH) discoloration assay described by Brand-Williams et al. (1995) with some modifications. Results of TAC are reported as Trolox equivalents (TE) mg 100 FW⁻¹. Significant differences of data between cultivation techniques were tested by one-way analysis of variance at significance level of $P \leq 0.05$. In the Figures mean values followed by the same letter are not significantly different at $P \leq 0.05$.

RESULTS AND DISCUSSION

The seed sowing and germination period was dry resulting in uneven establishment of carrot plants. A rainy period started on 10 June but did not alleviate the situation. This explains the low carrot yields. The marketable yield of organic carrots (10.9 t ha^{-1}) was 11% higher than conventional (9.7 t ha^{-1}), because of the higher proportion of damaged (cracked) carrots produced conventionally. Warman & Havard (1996), Fjelkner–Modig et al., (2000) and Rembialkowska (2000) have reported that, as a rule, organic yield is lower than conventional. Improved thermal regime and maintained humidity under the agryl cover probably raised the organic marketable yield. Earlier studies on broccoli (Kunicki et al., 1996) and carrot (Gimenez et al., 2002) have demonstrated the same effects of agryl cover. The applied humic acids fertilizer Humistar might be another contributor to the better yield of organic carrots. It is well established that humid acids improve soil chemical and physical quality and, in general, enhance root growth and development (Tan & Nopamornbodi, 1979; Bidegain et al., 2000; Canellas et al., 2002; Arancon et al., 2003). From the five analysed pesticide residues, two were detected in the conventionally grown carrots and none in organically grown carrots. These results concur with those of Rembialkowska & Hallmann (2007), who also found that organic vegetables were free of pesticide residues. Contaminants were determined as follows: boscalid 0.320 mg kg^{-1} and pyraclostrobin 0.090 mg kg^{-1} . According to EU regulation No 149/2008, the residues found did not exceed permitted levels but may be hazardous to consumers due to synergy between the two residues.

No significant differences were found between organic and conventional cultivation in content of total sugars (6.5% and 6.0% respectively), P (0.3% and 0.3% respectively), K (1.7% and 1.7% respectively), Ca (0.4% and 0.4% respectively) and Mg (0.9% and 1.0% respectively). However, contradictory results have been reported. According to Polish scientists organic carrots contain more total sugars than conventional (Rembialkowska, 2003; Rembialkowska & Hallmann, 2007), but the content of K, Ca and Mg were similar in organic and conventional carrots (Rembialkowska, 2003). Warman & Havard (1996) also observed minor differences in mineral content between the organic and conventional management systems. Yet, Worthington (2001) has found that organic crops contain significantly more Mg and P than do conventional crops. Our organically and conventionally grown carrots did not differ significantly in their DM content (10.9% and 10.8%, respectively). According to earlier studies by Leszczyn'ska (1996) and Fjelkner-Modig et al. (2000) organically grown crops (including carrot) had higher DM content compared with conventional ones. Kaack et al. (2002) found that DM content decreased linearly with increasing amount of nitrogen applied. SSC of organically grown carrots ranged from 8.6 to 9.2°Brix and of conventionally grown from 8.5 to 9.1°Brix. The average SSC of both carrots was 8.9° Brix and was not affected by cultivation technology. Vitamin C content in carrots harvested from the organic plot was significantly lower than that of conventional plot (5.0 and 6.2 mg %, respectively) (Fig. 1). Vitamin content of a plant depends on a number of factors such as climate, genetic properties, fertilizer and soil (Mozafar, 1994). Contradictory results have been reported by Worthington (2001), i.e. organic crops (among them carrot) contain significantly more vitamin C than

conventional crops. However, several scientists (Warman & Havard, 1996; Warman & Havard, 1997; Fjelkner-Modig et al., 2000) could not verify significant differences in vitamin C content caused by different cultivation systems. The average β -carotene content in organically grown carrots was $4908 \mu\text{g } 100\text{g FW}^{-1}$ and in conventionally grown carrots $5186 \mu\text{g } 100\text{gFWg}^{-1}$ (Fig. 1). These are a bit lower than found by Dutta et al. (2005), who reported β -carotene content of fresh carrots to be $84 \mu\text{g g}^{-1}$ and a bit higher than reported by Yen et al. (2008), who found β -carotene content in carrots to range from 0.11 to 0.28 mg g^{-1} . In our experiment conventional cultivation significantly increased β -carotene content in carrots. β -carotene is widely known as provitamin A and is reported to protect against cancer, cardiovascular disease (Breithaupt & Bamedi, 2001) and to enhance immune responses (Kurilich et al., 1999). However, these presumed benefits are highly contested, since all epidemiological studies of β -carotene intake were confounded with intake of the cancer-preventing compound falcarinol (Kobaek-Larsen et al., 2005), which is mainly found in carrots, and rodents metabolise β -carotene differently from humans (Wang et al., 1991). The role of β -carotene as an antioxidant has been widely reported (Terao, 1989; Palozza & Krinsky, 1992), however, tests of high doses ($>10 \text{ mg day}^{-1}$) of this and other antioxidants consistently increased mortality (Bjelacovic et al., 2008).

In our experiment, TAC of organically-grown carrots was $24.5 \text{ TE mg } 100\text{gFW}^{-1}$ and of conventionally grown carrots $25.7 \text{ TE mg } 100\text{gFW}^{-1}$. Cultivation technology did not affect TAC significantly.

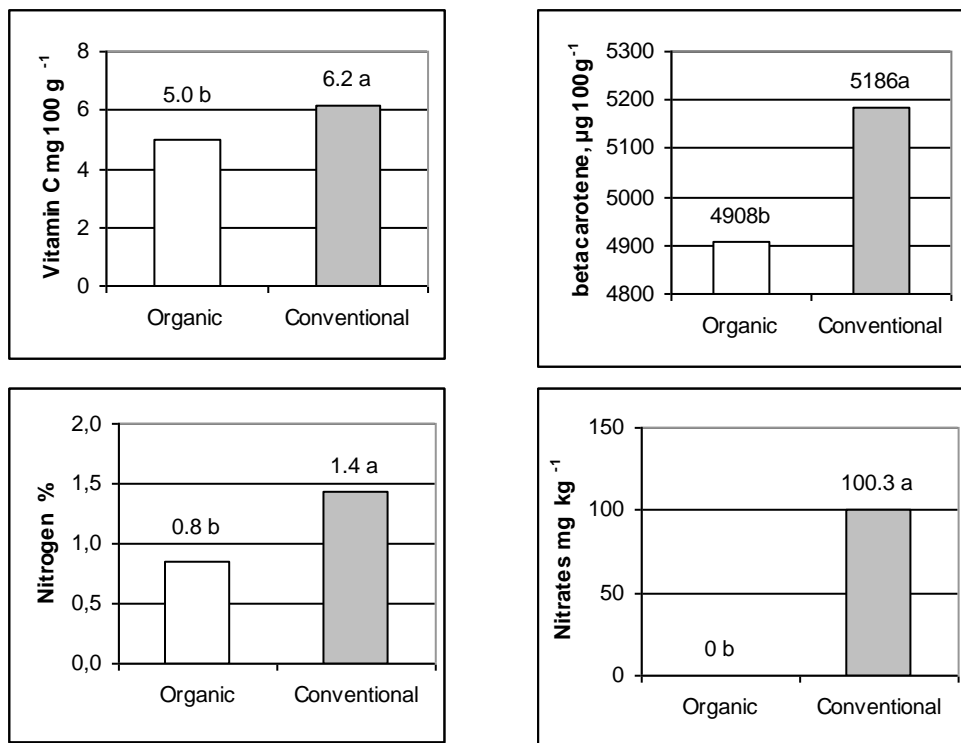


Fig. 1. Vitamin C, β -carotene, nitrogen and nitrates content of organically and conventionally grown carrots.

Nitrogen content was significantly higher in conventional vs. organic carrots (1.4 and 0.8%, respectively) (Fig. 1). Nitrates were not detected in organically grown carrots, whereas conventional carrots contained 100.3 mg kg⁻¹ of nitrates (Fig. 1). Several studies have affirmed that organic carrots consist significantly less nitrogen and nitrate than do conventional (Leclerc et al., 1991; Leszczyn'ska, 1996; Warman & Havard, 1997; Rembialkowska, 2000; Rembialkowska, 2003; Rembialkowska & Hallmann, 2007; Zdravkovic et al., 2007).

CONCLUSIONS

Organic production of the carrot variety 'Jõgeva Nantes' increased marketable yield compared with conventional production. Cultivation technology did not significantly influence the contents of dry matter, mineral compounds, total sugars and TAC value, but the quality of conventional carrots was significantly decreased by their high nitrate and pesticides residue content, both absent from the organic carrots, while the organic ones had lower contents of vitamin C (-24%) and β -carotene (-6%).

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